EXAMINATION QUESTIONS

for

Certificates of Competency

As Mine Inspector, Mine Foreman
Mine Manager, Fire-Boss
Hoisting Engineer, Etc.

AS GIVEN BY

THE STATE EXAMINING BOARDS

Together With Answers Prepared and
Edited by the Editors of
Mines and Minerals

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PREFACE

A system of governmental inspection of mines and of certificated mine officials was in operation in England and on the continent of Europe for a number of years prior to the introduction of a similar system in America. As is generally the case, it needed a great disaster to impress upon the American people the necessity for conducting so hazardous a business as coal mining must ever be, under legal restrictions and under officials who have theoretical as well as practical training.

On September 6, 1869, an anthracite breaker, situated over the mouth of the shaft at Avondale, Pennsylvania, was burned; and as this shaft was the only opening to the mine, the 108 men who were at work in the mine were asphyxiated. This disaster directed widespread attention to the conditions at the coal mines of the country and as a result of this popular agitation, the legislature of Pennsylvania, on March 3, 1870, passed the first general law ever passed in the United States for the regulation and inspection of coal mines. This law applied only to the anthracite mines, as particular attention had been directed to them by the Avondale disaster. The salient provisions of the law were the employment of mine inspectors to see that the mine laws were carried out and that all accidents were investigated; the accurate and systematic mapping of the mine workings; provision for at least two openings at a mine, both equipped so that they could be used as an escape way in case of accident; and a provision for a certain quantity of air for each person employed in the mines.

In 1877, a similar law was enacted for the bituminous mines of Pennsylvania; and in 1885, a law was passed providing for certificated foremen and assistant foremen. Other states followed the lead of Pennsylvania, usually providing first for an inspection service and later for certificated officials, although in a few instances the first law covered both of these items. As the Pennsylvania

law was based originally upon the English, and other European laws, so the other states, to a greater or less extent, based their laws on the Pennsylvania code. The laws as at first enacted in the several states have been modified to suit local conditions, and while there is still a general similarity in the state coal-mining regulations, they differ in details, as is illustrated by the requirements for certificated positions given in the following pages.

Nearly all the coal-mining states now have an inspection service; and in many states the appointment or election of the inspector is based on a preliminary educational test, combined with a certain period of practical experience in mining. In many states, an educational test is also required, in addition to practical experience, for other official positions about the mines, and this list of states is constantly increasing, for it is a recognized fact that coal mining is safer under certificated and educated officials than under those who are not thus equipped. A mine of today is a very different proposition from one of 30 years ago; and the applications of steam, compressed air, and electricity on the surface and underground, and the working of deep, thin, gaseous, and watery mines have introduced problems in mine management that require technical knowledge for their solution.

The questions and answers given in this book are mainly those that have already appeared in The Colliery Engineer and Metal Miner, or in Mines and Minerals; the answers as originally given have been edited and rearranged so that there may be as little duplication as possible in question or answer. Certain questions have been added from a file of unpublished examination questions, and it is thought, therefore, that this compilation faithfully and fully represents the range of subjects covered at the present time by examinations for certificated mining positions in the United States and Canada.

No attempt has been made to introduce questions that have not appeared in examinations already given in order to make each of the subjects inclusive and complete and so as to provide for questions that will probably be given by examining boards in the future. A study of the examinations given during the past few years shows that the questions are steadily growing more difficult. This is especially true in regard to those relating to such subjects as surveying, mechanics, and mining machinery.

This book is intended mainly to assist those preparing them-

selves for the state examinations for certificated mine positions. Although the questions are often answered and illustrated more fully than a candidate for certificate would be expected to answer them, no attempt has been made to explain the derivation of the formulas given or their use, except so far as is required by the examples given. None of the general principles or theories of mining are given other than those asked for by specific questions. The book is therefore intended not as a textbook but merely as an aid in connection with textbooks on mining.

In considering the answer given to a question, the position for which the examination was held and the locality in which the examination was held, as denoted by the Italics at the end of each question, must be considered, for certain questions have a purely local significance, while others are general in their character. For instance, questions involving a method of working under certain given conditions; questions asking for the size of entries, pillars, rooms, etc.; costs of operation, etc., often assume that the answer will be given in accordance with the local practice of the district in which the examination was held, and not always in accordance with general theoretical considerations. As far as possible, therefore, an effort has been made to have the answers agree with the local conditions. When the answer to a question depends entirely on the judgment and experience of the person answering, an attempt has been made to have the answers prepared, or at least checked, by some one in the given district who is familiar with the local conditions. It is impossible, however, to answer questions of this character so that the answers will be entirely satisfactory to every one, since it is seldom that two persons agree exactly in their judgment upon disputed points. Mining is very far from an exact science and in answers that depend on the judgment and experience, large latitude in answers must be expected. When it has been impossible or impracticable to give an exact answer on account of the local conditions called for by many of the questions, we have aimed to so frame our answers that they will show merely the general method of answering the question without giving exact figures, which might be misleading.

Questions upon the legal requirements as to the use of safety devices, the legal duties of officials, etc. may be answered either by quoting the law verbatim, or by giving an abstract of the law

covering all its essential features, but omitting the legal phraseology; the second type of answer shows an understanding of the law better than the first, but in questions of this character an example of each type of answer has usually been given. No attempt has been made in general, however, to answer the same or similar questions for every state or province in which the questions have been asked.

We believe that a person who will use this book in connection with the Coal Mining Course of the International Correspondence Schools, the Coal and Metal Miners' Pocketbook, Mines and Minerals, and the mining laws of the several states, will have no difficulty whatever in passing any examination for a certificated position about the mines of the United States or Canada.

THE EDITORS

Scranton, Pa., October 1, 1906

SUGGESTIONS TO CANDIDATES

An examination is to many a bugbear and something to be dreaded, and many who have to stand examinations get so worked up nervously by the time the examination begins that they are totally unstrung and unfitted to do themselves justice in the examination. This is particularly so with respect to an oral examination, which seems to be especially dreaded by most persons. This is just the opposite of what it should be, for while it is often difficult for persons who are unaccustomed to writing to express their ideas clearly in this way, an oral examination should be considered simply as a conversation upon mining matters with several gentlemen who are trying to bring out, as fully as possible, the candidate's knowledge of the subject and who are not simply trying to down the candidate, as so many seem to think. In such an examination, therefore, a person should forget, as far as possible, that he is being examined and should attempt to discuss the subject in question in a free and natural manner, just as he would in discussing any subject about the mines with a friend.

The following suggestions in regard to written work may be useful and suggestive, and if carried out will enable the person being examined to economize his time during the examination to the best advantage. First, read over all the questions given very carefully and then pick out and answer the easiest and most readily answered questions and those of whose answers you are most certain. Many make the mistake of thinking it necessary to begin with the first question and to attempt to answer the questions in order. By doing this, the person often uses up all the time allowed for the examination in trying to answer a few difficult questions; as the time approaches for closing the examination, he finds that there is not enough time left for him to answer the questions about which he is perfectly certain. Furthermore, after a certain number of questions have been answered a candidate

DEFINITION OF TERMS

The various official positions about mines are designated by different titles in different states or provinces, and the exact local significance of each title and the legal duties of the position in each locality can usually be best determined from the mine laws and rules of the several states. These laws and rules are usually included in the annual printed reports of the Bureau of Mines and they are also frequently obtainable in separate pamphlet form from the Bureau of Mines, from the mine inspector, or from a local book store.

The following general definitions are, however, given as a guide for the general understanding of the examination regulations which follow:

A *mine inspector* is an official employed by the state. He exercises a general supervision over the mines in his district to see that the state mine laws are enforced, and that proper precautions are taken by the mine operators to protect their workmen and to keep the mines in a sanitary condition. He is also usually required to investigate all accidents that result in the death or serious injury of workmen in and about the mines.

A *mine foreman*, *first-class foreman*, *mine manager*, or *overman* is an employe of a mining company. In general, he has charge of the underground operations of the mine and is usually directly responsible to the mine superintendent. In some states, a distinction is made between a first-class foreman or a foreman who holds a first-class certificate, which entitles him to have charge of a gaseous mine, and a second-class foreman, or one who holds a second-class certificate, which permits him to have charge of so-called non-gaseous mines, but not of a gaseous mine. In some cases, however, the term second-class foreman is synonymous with fire-boss. The term *mine manager* is used in British Columbia as equivalent to the term superintendent in the United States.

The *fire-boss*, *second-class mine foreman*, or *mine examiner* is

an employe of the mining company. His duty is to examine the mine for the presence of firedamp or other noxious gases before the miners enter the mine; in many cases, he also acts as assistant to the mine foreman in the general supervision of the mines and of the company hands.

The *shot firer* or *shot lighter* is an employe of the mining company whose duty it is to fire the shots that have been prepared by the miners, usually after all persons have left the mine except the shot firer.

The *hoisting engineer* is in charge of the engines used in hoisting and lowering men or material.

ABBREVIATIONS USED IN CONNECTION WITH THE QUESTIONS

Abbreviations used in connection with the questions.

F.—mine foreman
F_1.—mine foreman, first class
F_2.—mine foreman, second class
B.—fire-boss
I.—mine inspector
H.—hoisting engineer
E.—mine examiner
M.—mine manager
Ala.—Alabama
B. C.—British Columbia, Canada
Col.—Colorado
Ill.—Illinois
Ind.—Indiana
Ia.—Iowa
N. S.—Nova Scotia, Canada
Pa. (A).—Pennsylvania, anthracite
Pa. (B).—Pennsylvania, bituminous
Tenn.—Tennessee
Wash.—Washington

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EXAMINATION QUESTIONS

CHAPTER I

SURVEYING

MENSURATION

QUES. 1.—How many cubic inches are contained in a cylinder 18 inches in diameter and 36 inches in length? *F_2.—Ala.*

ANS.—Capacity of cylinder equals the area of the base, $.7854 \times 18^2 = 254.47$ sq. in., multiplied by the length of the cylinder;

$$254.47 \times 36 = 9{,}160.92 \text{ cu. in.}$$

QUES. 2.—A dirt heap has a slope of 45° measured by the clinometer; what is the height of the heap, the length of the slope from bottom to top being 45 feet? *M.—Ill.*

ANS.—The vertical height equals the slant height, or length of slope, multiplied by the sine of the slope angle or the angle the slope makes with the horizontal; thus,

$$h = 45 \times \sin 45° = 45 \times .70711 = 31.82 \text{ ft.}$$

QUES. 3.—How many cubic yards in a shaft 37 feet long, 12 feet wide, and 750 feet deep? *M.—Ill.*

ANS.— $$\frac{37 \times 12 \times 750}{27} = 12{,}333 + \text{cu. yd}$$

LAYING OFF RIGHT ANGLE

QUES. 4.—How would you proceed to lay off a right angle, using only a tape line? *M.—Ill.*

ANS.—There are numerous ways in which this may be done: (*a*) Lay off with the tape a distance *a b*, Fig. 1 (*a*), of 4 ft. on a line that is to form

one side of the angle. With a as a center and with a radius $a\,c$ of 3 ft., describe a short arc of a circle. Likewise, with b as a center and with a radius $b\,c$ of 5 ft., again describe a short arc of a circle intersecting the first; then draw the line $a\,c$ passing through the intersection of these two arcs, and the angle $b\,a\,c$ will be a right angle. Any multiples of the figures 3, 4, 5 may be used, as 6, 8, 10 : 9, 12, 15, etc.

(*b*) With any two points a and b, Fig. 1 (*b*), as centers, and with any convenient radius, describe short intersecting arcs on each side of the line $a\,b$; the line $c\,d$ joining these points of intersection will be perpendicular to the line $a\,b$ joining the centers, thus forming four right angles about the point o.

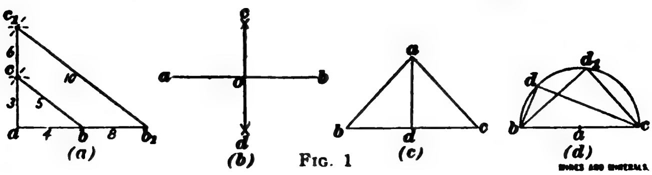


FIG. 1

(*c*) From a point a, Fig. 1 (*c*), measure two equal distances $a\,b$ and $a\,c$ in any convenient direction, and from the point a draw the line $a\,d$ to the middle point of the line $b\,c$; the angles $a\,d\,b$ and $a\,d\,c$ will then be right angles.

(*d*) From the point a, Fig. 1 (*d*), as a center, describe a semicircle, and from any point $d\,d_1$, etc. of the semicircle, draw lines to the extremities of the diameter, and the angle $b\,d\,c$, $b\,d_1\,c$, etc., will be a right angle. In other words, any angle inscribed in a semicircle is a right angle.

TRIANGLES AND QUADRANGLES

QUES. 5.—If a triangle has one angle of 65° 10′ and another angle of 70° 25′, what is the third angle? *M.—B. C., Canada*

ANS.—Since the sum of the three angles of a triangle is always 180°, the third angle, in this case, is

$$180° - (65°\ 10' + 70°\ 25') = 44°\ 25'$$

QUES. 6.—In a four-sided figure, three of the interior angles are, respectively, 72°, 95°, and 130°; how many degrees are there in the remaining angle? *M.—Ill.*

ANS.—The sum of the interior angles of any polygon is equal to twice as many right angles as the polygon has sides, less four right angles. In this case, the figure having four sides, the sum of all the interior angles is equal to $2 \times 4 - 4 = 4$ right angles, and the remaining angle is, therefore,

$$4 \times 90 - (72 + 95 + 130) = 63°$$

QUES. 7.—What is the area of a triangle, the sides of which measure, respectively, 230, 560, and 610 yards? *M.—Ill.*

ANS.—To find the area of a triangle when the three sides are given, find one-half the sum of the three sides and from this subtract each side

separately. Then find the continued product of these three remainders and one-half the sum of the three sides, and extract the square root of this product; the result will be the area of the triangle. Expressed as a formula, this rule is,

$$A = \sqrt{\frac{S}{2}\left(\frac{S}{2}-a\right)\left(\frac{S}{2}-b\right)\left(\frac{S}{2}-c\right)}$$

For one-half the sum, in this case,

$$\frac{S}{2} = \frac{230+560+610}{2} = 700;$$

then, $700-230 = 470$; $700-560 = 140$; $700-610 = 90$. Substituting these values in the formula, the area of the triangle is,

$$A = \sqrt{700\times 470\times 140\times 90} = 64{,}384 \text{ sq. yd.}$$

QUES. 8.—What is the area of a triangle, the sides of which are, respectively, 45, 63, and 92 yards? *M.—Ill.*

ANS.—The area of this triangle may be found as follows: First, find the altitude, or the length of the line drawn from the vertex of the greatest angle perpendicular to the opposite side or base. This perpendicular divides the base into two parts, and the product of the sum and the difference of these parts is equal to the product of the sum and the difference of the other two sides. Taking the longest side for the base, the sum of the parts is 92, and their difference is equal to the product of the sum and the difference of the other two sides divided by the third side; thus, calling the parts of the base x and y,

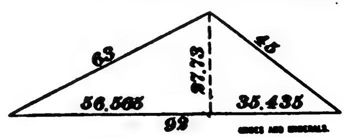


FIG. 2

$$x-y = \frac{(63+45)\,(63-45)}{92} = 21.13$$

Adding one-half the difference of the parts to one-half the sum gives $\frac{21.13}{2}+\frac{92}{2} = 56.565$, for the greater part lying adjacent to the greater side. The altitude is, then,

$$\sqrt{63^2-56.565^2} = 27.73 \text{ yd.};$$

and the area of the triangle is

$$A = \frac{92\times 27.73}{2} = 1{,}275.58 \text{ sq. yd.}$$

QUES. 9.—Find the length, in feet, of an arc of 40° 33′, the radius being 11 feet 6 inches. *M.—B. C., Canada*

ANS.—The circumference of a circle whose radius is 11 ft. 6 in. is

$$2\times 11.5\times 3.1416 = 72.2568 \text{ ft. (use 72.26)}$$

Since the circumference of a circle contains

$$360° = 60\times 360 = 21{,}600 \text{ min.}$$

and the required arc contains

$$60\times 40+33 = 2{,}433 \text{ min.}$$

the length of this arc (40° 39′) is,

$$\frac{2{,}433}{21{,}600}\times 72.26 = 8.139 \text{ ft.}$$

Ques. 10.—What is the area included in 60° of a circle, the radius of which is 50 feet? *M.—Ill.*

Ans.—The area of a full circle when the radius is 50 ft., is

$$3.1416\times 50^2 = 7{,}854 \text{ sq. ft.}$$

Since there are 360° in a full circle, the area corresponding to 60° of the given circle will be

$$\frac{60}{360}\times 7{,}854 = 1{,}309 \text{ sq. ft.}$$

Ques. 11.—Find the area and perimeter of an ellipse whose axes are 5 feet and 10 feet, respectively. *I.—Pa. (A)*

Ans.—Area, $.7854\times 5\times 10 = 39.27$ sq. ft.

Perimeter, $3.1416\times\frac{5+10}{2} = 23.56$ ft.

BEARINGS OF LINES

Ques. 12.—What is the angle made by two lines, the bearings of which are, respectively, N 25° W and S 12° W? *M.—Ill.*

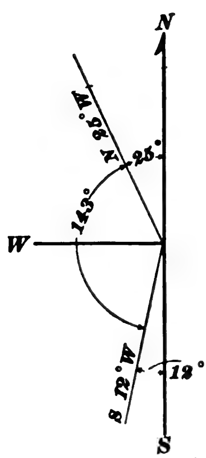


Fig. 3

Ans.—These lines lying on the same side of the meridian N S and their bearings being measured from the two opposite poles of this meridian, the sum of the angles of their respective bearings subtracted from 180° will give the angle between the lines; thus,

$$180° - (25° + 12°) = 143°$$

Ques. 13.—The bearings of two lines taken from the same point are N 27½° W and S 83° E; what is the angle made by the two lines? *M.—Ill.*

Ans.—The first line lying in the northwest quadrant, and the second in the southeast quadrant, the angle that the lines make with each other may be found by adding 180° to the bearing of the first line and subtracting from this sum the bearing of the second line. Thus,

$$27° 30' + 180° = 207° 30'$$

and

$$207° 30' - 83° = 124° 30'$$

Ques. 14.—In a triangle $A\,B\,C$, the side $A\,B$ runs due north, and $B\,C$ makes an angle of 120° with $A\,B$; what is the bearing of the side $B\,C$? *M.—Ill.*

ANS.—The angle between $A\ B$ and $B\ C$ being 120°, the line $B\ C$ lies in one of the south quadrants and makes an angle with the meridian of $180° - 120° = 60°$. Its bearing may then be either S 60° E or S 60° W, according to the side of the meridian on which the line lies, or the side of $A\ B$ on which the angle is measured.

QUES. 15.—How many degrees in a circle, and what angle is included between the bearings N 87½° E and S 15° W?

F.—Pa. (A)

ANS.—There are 360° in a circle, and the angle included between N 87½° E and S 15° W, is

$$180° - 87\tfrac{1}{2}° + 15° = 107\tfrac{1}{2}°$$

QUES. 16.—(*a*) What angle is included between N 60° E and N 25° W? (*b*) What angle is included between S 20° W and N 70° W? *F.—Pa. (A)*

ANS.—(*a*) The angle between the courses N 60° E and N 25° W is

$$60° + 25° = 85°$$

(*b*) The angle between the courses S 20° W and N 70° W is

$$180° - (20° + 70°) = 90°$$

QUES. 17.—If the bearing of the main entry in a mine is N 17¾° W, what is the bearing of a cross-entry turned from it to the right at an angle of 90°? *M.—Ill.*

ANS.—The required bearing of the cross-entry is N 72¼° E, since $90 - 17\tfrac{3}{4} = 72\tfrac{1}{4}$ and the line lies in the northeast quadrant.

MERIDIANS: DECLINATION, AZIMUTH

QUES. 18.—What is a true meridian? Explain how its direction is determined. *F.—Ia.*

ANS.—A true meridian on the earth's surface is a true north and south line formed by the intersection with the surface of the earth of a plane passing through the earth's axis of revolution.

There are two methods commonly used for determining a true meridian: (*a*) by reference to the position of the north star, and (*b*) by the use of the solar attachment to a transit.

The north star, not being in line with the extended axis of revolution of the earth, has an apparent revolution about the celestial pole. Twice in a stellar day (24 hr.) the north star crosses the true meridian; likewise, twice in the same time it is at its greatest distance from the pole, east or west. The star is then said to be at elongation, either east or west. If the exact moment when the star crossed the meridian plane were known, its

position at that time would determine the true meridian. The position of east and west elongation, however, is more readily obtained, since the star appears to move from the pole until it obtains its greatest elongation, and at that point appears to remain stationary for a few moments and then to recede. The times of the east and west elongation are obtained by observing the star with a transit, or the time of elongation may be taken from a nautical almanac. Some 10 min. before the time of elongation, the transit is carefully set up and leveled over a peg. The cross-wires, illuminated by a light held under the reflector fastened on the object end of the telescope, are made to bisect the star, and the star is followed with the cross-wires until its motion toward the point of greatest elongation ceases. The telescope is then lowered vertically, care being taken, of course, not to move it horizontally, and a peg is set up on the line, 300 ft. or 400 ft. distant. The next morning, the correction is made for the star's azimuth as given by the nautical almanac or other suitable tables.

To Find the True North With the Burt Solar Attachment.—Find from an ephemeris or nautical almanac the sun's declination for noon of the day of observation at Greenwich. Find the declination for the hour of observation at the place of observation by first figuring what time it is at the place of observation when it is noon at Greenwich. If the place of observation is west of Greenwich, it will be earlier there; if east, later; and in either case the difference will be 1 hour for every 15° of longitude. If the place is west of Greenwich, subtract the hour just found as described, from the hour of the observation, and multiply the hourly difference, also taken from the ephemeris, by the remainder. If the declination is increasing from the equator either north or south, add this product to it; if decreasing, subtract it. A table of refractions is given in the ephemeris for the different latitudes and the different hours of the day. This refraction is to be added if the declination is north, and subtracted if the declination is south. Having thus ascertained the declination, lay it off on the declination arc. Set the colatitude of the place off on the vertical arc after having leveled the instrument carefully with clamped horizontal plates at zero. In solar observations, it is well to level by means of the upper telescope bubble. Now, revolve the horizontal plates still clamped, and also the declination arc, around its polar axis until the sun's image is exactly between the horizontal lines of the silver plates. When the sun's image is between these lines, the object end of the telescope will be pointing north.

QUES. 19.—What is meant by the magnetic meridian of any place or point? *M.—Ill.*

ANS.—The magnetic meridian is any great circle passing through the magnetic poles of the earth. The direction of the magnetic meridian at any place is indicated by the position of the magnetic needle at that place, assuming that the needle is not affected by local attraction. The magnetic meridian may deflect to the right or left of the true meridian, or may correspond to the same, according to the position of the place where the observation is taken.

QUES. 20.—What is meant by declination? Give the declination of any point known to you. *M.—Ill.*

ANS.—The angular divergence of the magnetic meridian from the true meridian at any place is called the declination for that place. The declination may be either east or west according as the magnetic meridian deflects to the right or the left of the true meridian. What is known as the *agonic line* is a line passing through all points of no declination. All places lying on this line have no declination; places lying east of this line have a west declination, and places lying west of the line have an east declination. The declination of any place is not constant, but changes from year to year at about the rate of 3 min. each year. At the present time, west declination is increasing and east declination is decreasing, as the agonic line is slowly moving westwards. The declination for places in Illinois, at the present time, is east and varies from 4° to 6°.

QUES. 21.—What is meant by declination and variation when speaking of the compass? *M.—Ill.*

ANS.—The term declination describes the angular divergence of the magnetic meridian from the true meridian, at any place, and is the amount the magnetic needle varies from the true north at that place. The term variation properly refers to the change that the declination of the needle constantly undergoes; there is a daily and annual variation in the declination of the needle. The term *variation*, however, is very commonly, though wrongly, used to describe the *declination* of the needle.

QUES. 22.—What is meant by the true azimuth, and what by the magnetic azimuth? *I.—Ill.*

ANS.—The azimuth of a line is its bearing or direction expressed in angular measurement referred to any assumed meridian. The true azimuth is always referred to the true meridian. The magnetic azimuth is referred to a magnetic meridian, whose north end may deflect to the right or left of the true meridian according as the declination of the needle is east or west. In Fig. 4, $N\ S$ represents the true meridian drawn through any point of observation O. The declination, often called the magnetic variation, is assumed in this case to be 5° 15′ E. The dotted line drawn through O represents the magnetic meridian, the north end of this meridian being deflected 5° 15′ to the right or east of

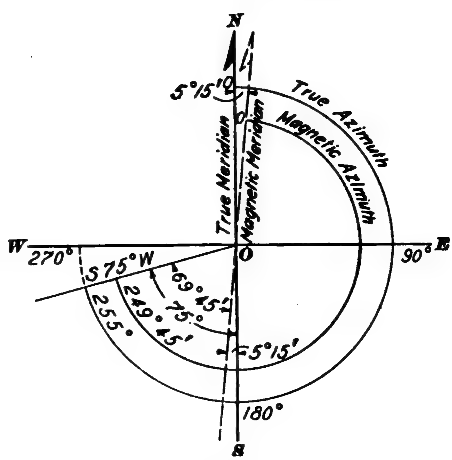


FIG. 4

the true meridian. The true azimuth of any line in surveying is usually measured from the north end of the true meridian as zero, around to the right, or in the direction of the clock. Magnetic azimuths are measured in the same manner, but starting from the north end of a magnetic meridian as zero. When the declination is east as in this case, it is clear that the magnetic azimuths are equal to the true azimuths less the declination of the needle; when the declination is west, the magnetic azimuths are equal to the true azimuths increased by the declination of the needle.

QUES. 23.—The magnetic bearing of an entry is N 84° 30′ E; if the declination of the needle is 5° E, what is the true bearing of the entry? *M.—Ill.*

ANS.—Since the declination in this case is 5° E, the true meridian is to the left of the magnetic meridian, while the position of the entry is 84° 30′ to the right of the same meridian. Hence, the angle that this entry makes with the true meridian is $84° 30' + 5° = 89° 30'$, and the true bearing of the entry is, therefore, N 89° 30′ E.

COMPASS SURVEYING

QUES. 24.—What are the different instruments neccssary for the use of a mine foreman to run a mine as required by law and for his employer's interest, and what are their uses? *F.—Pa. (B)*

ANS.—In addition to the instruments named and described in the chapter on Ventilation, the mine foreman should also be provided with a compass for the purpose of surveying small portions of the working places or giving sights for the driving of entries or rooms. While the regular mine survey is or should be made with a transit by an engineer, the mine foreman or his assistant is frequently called on to give sights or bearings or even to make a temporary survey.

QUES. 25.—Does the needle of a miner's compass point due north and south when at rest? If not, in what direction does it point? *M.—Ill.*

ANS.—The compass needle points due north and south only when the compass is on the agonic line. In the state of Illinois, at the present time (1906), the compass needle when at rest and not influenced by local attraction, points from about 4° to 6° east of the true geographical north; in other words, the mean declination of the magnetic needle in that state is at present about N 5° E.

QUES. 26.—Why is it not advisable to use the compass needle in making a survey of a mine? *M.—Ill.*

ANS.—The needle is not a reliable means of obtaining the true direction of a line, inasmuch as it is subject to local attraction, which may exist at

any point without being observed. In mine entries and rooms, in particular, there are often iron rails or mining tools lying near that may exert considerable influence on the needle and deflect it from its true position. When using the needle, it is necessary to check the bearings of a line from at least two positions of the compass to avoid the danger of local attraction.

QUES. 27.—How can you make certain that your compass gives a correct reading on any course? *M.—Ill.*

ANS.—The usual method is to take both foresight and backsight readings on the same course or line, and observe if these agree; if they do not agree, intermediate points are established on the same line and readings taken at these points also, until two or more readings are obtained that correspond; or a line may be extended in either direction to obtain other points where readings may be taken.

QUES. 28.—In making a mine survey with a compass, what precautions would you take to satisfy yourself that your bearings were correct? *M.—Ill.*

ANS.—At each setting of the compass, both backsight and foresight readings should be taken. If the readings taken at the two ends of the same line do not correspond, the correct reading can generally be detected by comparison with the foresight and backsight readings of the preceding or following course. If the vernier compass is used, the deflection angle at each station is carefully read, and this will also prove a valuable check on the needle readings. Where it is impossible to obtain correct needle readings, the line should be prolonged by survey of deflection angles to a point more remote in the workings where there is no attraction, and a careful needle reading taken at this point.

QUES. 29.—What are the advantages of a transit over a compass when making a mine survey? *F.—Ia.*

ANS.—A transit can be much more accurately sighted than a compass, as it is provided with a telescope, while the compass has sights only, consisting of two vertical uprights attached to the graduated circle of the compass, and having narrow slits through which the sight is taken. One, or both, of these slits is provided with a horsehair or fine wire. The telescope of a transit may also be elevated or depressed, which gives it a great advantage over the compass in surveying inclined seams. Again, the vernier of a vernier compass is often arranged to only admit of a small angle being turned off or deflected, while with a transit the telescope may be deflected through any angle. Also, the graduations of the circle and of the vernier are finer and more accurate in a transit than in a compass, and angles and bearings can be much more accurately determined. With a transit having a bubble tube attached to the telescope, and a vertical arc, elevations can be carried; but not with a compass.

QUES. 30.—How can you lay off a line running north and south with a common surveyor's compass? *M.—Ill.*

ANS.—In order to run a true north-and-south line with a plain compass having no variation plate, allowance must be made for the declination, when reading the needle. For example, the declination of the needle in Illinois at the present time (1906) varies from 4° to 6° E. In running a north-and-south line, therefore, with a plain compass, the needle should indicate an angle equal to the declination.

QUES. 31.—The bearing of an entry taken from the mine map is S 75° W, and the declination $5\frac{1}{4}$° E, how would you give correct sights on this entry with a plain compass? *I.—Ill.*

ANS.—The declination in this case being $5\frac{1}{4}$° E, the magnetic bearing of the entry is $75° - 5\frac{1}{4}° = 69\frac{3}{4}°$; or, S $69\frac{3}{4}$° W; this is, therefore, the required reading of the compass needle.

QUES. 32.—The bearing of an entry taken from the map is S 80° E, and the declination of the needle is 7° 30′ W; to give correct sights on this entry with a compass, what magnetic bearing would you use? *I.—Ia.*

ANS.—Reducing this bearing to azimuth, the true azimuth of the entry is $180° - 80° = 100°$. Since the declination of the needle is 7° 30′ W, this is added to the true azimuth to obtain the magnetic azimuth; thus, magnetic azimuth is $100° + 7°\ 30' = 107°\ 30'$. Then, $180° - 107°\ 30' = 72°\ 30'$; or the magnetic bearing of the entry is S 72° 30′ E.

QUES. 33.—Placing the compass at the mouth of a cross-entry and sighting along the main entry, we find its bearing to be N 8° W; and the bearing of the cross-entry N 84° E. These entries should be at right angles to each other, and the main entry should have a due north course. Are the sights properly placed? If not, how much of an error has been made in putting them up, and in which of the entries has the error been made? *M.—Ill.*

ANS.—If the magnetic declination is assumed to be 6° E, the true north, in this case, will be 6° west of the magnetic north; and the magnetic bearing for the main entry running north will be N 6° W, instead of N 8° W, as given. Then, if our supposition is correct, the sights on the cross-entries are correct, while those on the main entry are wrong; the latter vary 2° to the west from their true position, making the angle between the entries 92° instead of 90°.

SIGHTS

QUES. 34.—How do you proceed to put up sights for the guidance of miners in driving their working places? *M.—Ill.*

ANS.—When using the ordinary plain compass, the instrument is first set over one of the survey stations on the entry or gangway, and leveled and sighted to the next survey station on the entry and clamped. Points are then established in the roof or floor opposite the mouth of each chamber in which sights are to be given. The compass is now moved to each of these intermediate points in succession, and after being leveled up is sighted carefully on one or both of the survey stations previously mentioned. In this position, a careful reading is taken of the needle, which is first lowered and allowed to come to rest. The compass plate is then unclamped and turned through 90° of azimuth if the rooms are to be driven at right angles to the entry; or, where the rooms are driven at an angle with the entry, the compass is deflected through the required angle, by observing the reading of the needle, which remains stationary while the plate is being moved in azimuth. The instrument is clamped in this position, and sight lines are now hung from the roof some distance from the face (so as not to be disturbed by blasting) and some yards apart. The method of hanging these sights will depend on the nature of the roof. When practicable, a small hole is drilled in the roof in line with the instrument, and a wooden plug driven tightly into this hole; a small nail, tack or screweye, driven in the plug, holds the sight strings in position. After the sights have been placed, they are again tested with the instrument to see that they are correct.

QUES. 35.—How would you proceed to put up sights in a room, the course of the entry being given as N 86° E, and the rooms to be turned to the left, and to make with the entry an angle of 72°? *M.—Ill.*

ANS.—In this case, the bearing of the room is N 14° E, since $86° - 72° = 14°$; and, assuming that the declination for the place in Illinois where the mine is located is 5° E, and subtracting this declination of the needle from the true bearing, thus, $14° - 5° = 9°$, the magnetic bearing of the sight line in the room is then N 9° E. Using a plain compass, the instrument is first set up and leveled on the entry, and the needle is lowered and allowed to come to rest. Keeping the south end of the compass plate toward him, the observer moves the plate to the right or left until the needle reads N 9° E. In this position, the true bearing of the compass sights is N 14° E, inasmuch as the needle bears 5° to the east of the true meridian at this place. The compass is clamped in this position and the sights are put up in the roof in the usual way.

LATITUDES AND DEPARTURES

QUES. 36.—An entry runs west 100 feet, thence north 135 feet, thence west 140 feet, thence north 165 feet, thence west 160 feet; what is the length of a straight line from start to face? *I.—Ia.*

ANS.—The total northing equals $135+165 = 300$ ft.; the total westing equals $100+140+160 = 400$ ft. The required distance from start to face is then

$$\sqrt{300^2+400^2} = 500 \text{ ft.}$$

QUES. 37.—A point that may be designated as B is 33 yards east of another point A; a third point C is 18 yards north of B and a fourth, D, 24 yards east of C. What is the distance from A to D? *I.—Ia.*

ANS.— $$A\,D = \sqrt{18^2+(24+33)^2} = 59.77 \text{ yd.}$$

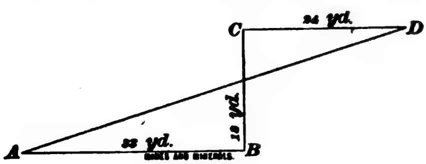


FIG. 5

QUES. 38.—A line is run from a point A, in a direction N 45° W, 2,640 feet, and thence N 45° E, 2,640 feet to B; what is the direction and length of a straight line that will connect the two points A and B? *F.—Ia.*

ANS.—Calculating the latitude and departure for each of the given courses it is found that the first course has a northing of $2,640\times.7071 = 1,866.7$ ft., and a like westing; the second course has also a northing of 1,866.7 ft., and a like easting. The total northing, or latitude, of these courses is, therefore,

$$1,866.7+1,866.7 = 3,733.4 \text{ ft.};$$

while the total departure is zero. The point B is then 3,733.4 ft. due north of A.

QUES. 39.—Commencing at the southwest corner of section 28, and running a line N 45° W, 2,800 feet; thence, N 45° E, 3,100 feet, what will be the length and bearing of a line that will close the figure? How many acres will there be in this piece of land? *M.—Ill.*

ANS.—Since the sine and cosine of 45° are each .70711, the northing and westing of the first course are each $2,800\times.70711 = 1,979.9$ ft., and the northing and easting of the second course are likewise each $3,100\times.70711 = 2,192.0$ ft. The total latitude and departure are, therefore, as follows:

$$\text{Lat.} = 1,979.9+2,192.0 = 4,171.9 \text{ ft.};$$

and

$$\text{Dept.} = 2,192.0-1,979.9 = 212.1 \text{ ft.}$$

Hence, the closing course will have a southing of 4,171.9 ft. and a westing of 212.1 ft. Dividing the westing by the southing, we have, for the tangent of the bearing of the closing course, $212.1 \div 4{,}171.9 = .05084$; and the bearing of this course is, therefore, S 2° 55′ W. Again, dividing the westing by the sine of this bearing gives for the length of the closing course $212.1 \div .05077 = 4{,}177.6$ ft. Since the first course is perpendicular to the second, the area enclosed by this survey may be found by multiplying one-half the length of the first course by the length of the second course, and dividing their product by the number of square feet in an acre; thus,

$$\frac{2{,}800}{2} \times 3{,}100 \div 43{,}560 = 99.6 \text{ A.}$$

QUES. 40.—Commencing at the southwest corner of the southwest quarter of section 26, and running north 2,640 feet, and thence east 1,320 feet, how many Gunter's chains will it take to close the figure, and what will be the bearing of the closing course? How many tons of coal will there be in this piece of land, allowing 27 cubic feet to the ton, the coal to be 4.5 feet thick? *M.—Ill.*

ANS.—Since the total northing is 2,640 ft., and the total easting 1,320 ft., the closing course will have a southing of 2,640 ft., and a westing of 1,320 ft. The tangent of its bearing is, therefore, $1{,}320 \div 2{,}640 = .5$, making the angle of the bearing 26° 34′. The bearing of the closing course is, therefore, S 26° 34′ W. The area of the survey is

$$\frac{2{,}640 \times 1{,}320}{2 \times 43{,}560} = 40 \text{ A.}$$

Allowing 27 cu. ft. to the ton, the weight of coal underlying this land is

$$\frac{2{,}640 \times 1{,}320 \times 4.5}{2 \times 27} = 290{,}400 \text{ T.}$$

QUES. 41.—The survey of a piece of land gave the following bearings: N 39° E, S 80° E, S 20° E, S 5° W, N 45° W, N 30° E; state how many right angles the sum of the interior angles would make, and give each and every interior angle, numbering your angles *A*, *B*, *C*, etc. *I.—Pa. (B)*

ANS.—Assuming that this is a closed survey, the sum of the interior angles of the survey is equal to twice as many right angles as there are lines or courses, less four right angles. In this case, there being six courses in the survey, the sum of the interior angles of the survey is $2 \times 6 - 4 = 8$ right angles. The interior angles are as follows:

A, $39 + 80 = 119°$
B, $180 - 80 + 20 = 120°$
C, $180 - (20 + 5) = 155°$
D, $5 + 45 = 50°$
E, $180 - (45 + 30) = 105°$
F, $180 + 30 - 39 = 171°$

The sum of these angles is

$$119 + 120 + 155 + 50 + 105 + 171 = 720°$$

and $720 \div 90 = 8$ right angles.

DIRECTION AND DISTANCE OF DRIVING

QUES. 42.—A cross-entry is driven at right angles to the main entry and reaches the bottom of a dip after going 175 yards. From the shaft to the point where the cross-entry is turned is 700 feet. It is proposed to drive a water level in a straight line from a point on the main entry 200 feet from the shaft, to the foot of the dip in the cross-entry; what is the distance? *F_2.—Ind.*

ANS.—The distance cut off on the main entry is $700-200 = 500$ ft.; the distance on the cross-entry is $175\times3 = 525$ ft. The length of the water-level cut-off is then

$$\sqrt{500^2+525^2} = 725 \text{ ft.}$$

QUES. 43.—A cross-entry is driven at right angles from the main entry a distance of 800 feet, when a heavy fall occurs, closing it completely. The fall is so extensive that it is concluded not to try to reopen the entry, but to recover it by a roadway driven across the old workings, beginning from a point back on the main entry 300 feet. How would you lay off, with a tape line, a course from this point to reach the head of the closed entry? *I.—Ill.*

ANS.—A roadway starting from the main entry 300 ft. back from the mouth of the cross-entry, in order to reach the head of this entry, bears away from the main entry 800 ft. in going 300 ft., or 8 ft. in 3. Therefore, to lay off such a road with a tape line, from the point of the main entry where it is proposed to start the road, measure 3 ft. on the center line of the entry, and from that point measure 8 ft. at right angles to this line and in the direction of the cross-entry. The point so obtained, together with the starting point on the main entry will give the direction of the roadway.

QUES. 44.—The main entries in a mine run due north. At a point 1,760 feet from the shaft bottom a cross-entry has been run due east for a distance of 850 feet. This entry is lost by a "squeeze," and to recover the field, it is resolved to cut through the old works to the face of the cross-entry, beginning at a point 910 feet from the shaft. What will be the distance across the old works to the face of the lost entry; and on what course will this cut-off run? *M.—Ill.*

ANS.—The distance cut-off on the main entry is $1{,}760-910 = 850$ ft.; and the face of the cross-entry is 850 ft. from the main entry; the bearing of the cut-off is, therefore, N 45° E, and the distance across the old works is

$$\sqrt{850^2+850^2} = 1{,}202+ \text{ ft.;}$$

or,

$$850\times.7071 = 1{,}202+ \text{ ft.}$$

ROOM CENTERS

QUES. 45.—A gangway is driven S 60° E, the chambers are driven N 85° E, the width of chamber pillars is 30 feet, the width of chambers is 30 feet; find the distance on gangway from center of chamber to center of chamber. *F.—Pa. (A)*

ANS.—The angle that the chambers make with the gangway is

$$180° - (85° + 60°) = 35°$$

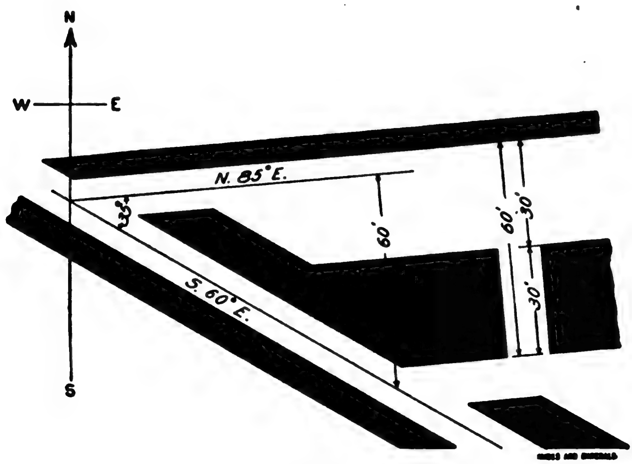


FIG. 6

The distance from center to center, square across the chamber is

$$30 + 30 = 60 \text{ ft.}$$

Then, the distance between centers, measured on the gangway, is

$$60 \div \sin 35° = 60 \div .57358 = 104.6 \text{ ft.}$$

QUES. 46.—A gangway is driven N 50° E, the breasts, N 10° W; the pillars are 30 feet wide, the breasts, 24 feet wide; what is the distance between centers of breasts, measured on the gangway? *F.—Pa. (A)*

ANS.—The angle between the gangway and the breasts is, in this case, $10 + 50 = 60°$; and the distance between centers square across chambers, $30 + 24 = 54$ ft. Then, the distance between centers, measured on the gangway, is

$$54 \div \sin 60° = 54 \div .866 = 62.36 \text{ ft.}$$

QUES. 47.—From a gangway running N 62° 30′ E, it is proposed to drive chambers S 73° 30′ E. If the chambers are 28

feet wide and the pillars 18 feet wide, what should be the distance from center to center of chambers, measured on the gangway?

F.—Pa. (A)

Ans.—In this case, the angle between the breasts and the gangway is

$$180° - (62° 30' + 73° 30') = 44°$$

and the distance square across chambers, center to center, $28+18 = 46$ ft. Hence, $46 \div \sin 44° = 46 \div .69466 = 66.2$ ft.

Ques. 48.—Suppose that the cross-entry from which rooms are turned runs at an angle of 45° to the main entry, what distance must be measured on the cross-entry to get rooms 20 feet wide, with 12-foot pillars between them, when the rooms are made parallel to the main entry?

F.—Ia.

Ans.—Since, in this case, the angle between the rooms and the cross-entry is 45°, and the distance square across the rooms, center to center, is $20+12 = 32$ ft., the distance from center to center of the rooms measured on the cross-entry is $32 \div \sin 45° = 32 \div .7071 = 45.25$ ft.

Ques. 49.—If you are driving rooms 30° off the entry, how far apart would you turn the rooms in order to have each room 35 feet wide and leave a 25-foot pillar between them?

F_1.—Ala.

Ans.—The entire width of room and pillar, measured square with the rooms, is $35+25 = 60$ ft. Then,

$$60 \div \sin 30° = 60 \div .5 = 120 \text{ ft.}$$

is the distance from the center of one room, measured along the entry, to the center of the following room, or the distance measured on the entry from the point where the straight rib of one room intersects the entry, to the point where the straight rib of the next room intersects the entry.

Ques. 50.—An entry is driven, one-half on the face and one-half on the butt, a distance of 2,000 feet, how many rooms can be turned on this entry, allowing 13 feet for width of rooms and 12 feet for width of pillars, and leaving 100 feet of barrier pillar at each end of the entry; and what will be the distance between the rooms on the entry in order to have both rooms and pillars uniform in width and thickness?

F.—Pa. (B)

Ans.—Assuming that the rooms are driven on the face and thus make an angle of 45° with the entry, the width of each barrier pillar measured on the entry is $100 \div \sin 45° = 100 \div .7071 = 141.42$ ft.

The distance between centers of rooms will measure, on the entry,

$$\frac{13+12}{\sin 45°} = \frac{25}{.7071} = 35.35 \text{ ft.}$$

From the total length of the entry subtract the length required for two barrier pillars and add the entry length for one pillar, $12 \div .7071 = 16.97$,

say 17 ft., as the number of rooms will be one more than the number of pillars; thus,

$$2{,}000 - 2(141.42) + 17 = 1{,}734+ \text{ ft.}$$

Dividing this result by the entry distance between room centers, the number of rooms that can be turned off from this entry is

$$1{,}734 \div 35.35 = 49 \text{ rooms}$$

The distance from center to center between the rooms on the entry, in order to have both rooms and pillars uniform in width, will be equal to

$$\frac{2{,}000 - (141.42 \times 2)}{48.5} = 35.35 \text{ ft.}$$

QUES. 51.—The bearing of the main entry in a mine is N 30° W, and that of a cross-entry from it N 30° E. Rooms turned off the cross-entry run parallel to the main entry. If the perpendicular distance between the centers of the rooms is 36 feet, what distance should be measured on the entry between their centers? Sin 30° = .5; cosine 30° = .86603; sin 60° = .86603; cosine 60° = .5. *I.—Ia.*

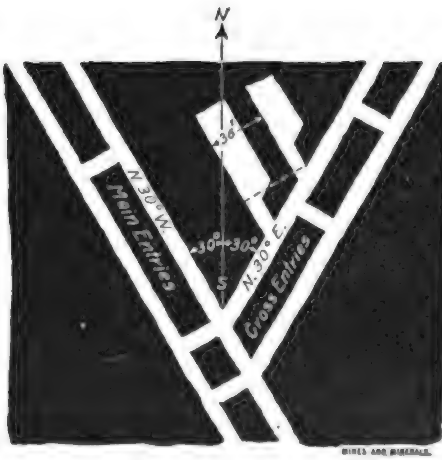


FIG. 7

ANS.—The angle between the rooms and the entry, Fig. 7, is found by adding the two bearings together; thus, 30° + 30° = 60°. The perpendicular distance between the centers of the rooms being 36 ft., the distance between the centers measured on the entry is

$$36 \div \sin 60° = 36 \div .866 = 41.57 \text{ ft.}$$

QUES. 52.—An entry runs parallel to a land line and 150 feet from it; if the rooms turned off the entry run at an angle of 45° with the entry, what distance can they be driven? *F.—Ia.*

ANS.—Assuming the seam to be level, the length of the rooms will be

$$150 \div \sin 45° = 150 \div .7071 = 212 \text{ ft.}$$

ACCURATE MINE MAPS

QUES. 53.—Of what use is a correct map of a mine to a foreman? *F.—Pa. (A)*

ANS.—It enables him to lay out his work systematically and also shows him his nearness to boundary lines and other points of danger. Where several overlying seams are being worked, such a map will enable the mine foreman to keep pillar under pillar and room under room.

QUES. 54.—What are the dangers and the consequent results arising from not having accurate and complete surveys of the workings of a mine? *F.—Pa. (B)*

ANS.—The lack of accurate and complete surveys of the mine workings may result in: (*a*) Encroachments on neighboring properties bringing about expensive litigation. (*b*) Driving into the old gobs of deserted mines and encountering large volumes of gas and water that may require for their removal the expenditure of much more money than would have been required for a complete survey of the workings. (*c*) Loss of coal, as the result of not knowing the correct limits of the lease. (*d*) Troubles with creeps in the panels and the entries as the result of roads and rooms having been set away on wrong bearings. (*e*) Loss of coal areas not shown properly on the map. In this case, the mine map does not supply the means of checking the efficiency of the mine management.

MINE-MAP CALCULATIONS

QUES. 55.—On a plan, the scale of which is 6 chains to an inch, how many acres would 1 inch square represent? *M.—B. C., Canada*

ANS.—The area represented is $6 \times 6 = 36$ sq. ch., or since 10 sq. ch. make 1 A.,

$$36 \div 10 = 3.6 \text{ A.}$$

QUES. 56.—Explain how mine workings are plotted on the map and to what scale. If between two lifts shown on a map there is a horizontal distance of 150 feet, and a vertical distance of 200 feet, what is the pitch distance and what is the average pitch? *F.—Pa. (A)*

ANS.—Mine maps are required by the anthracite mine law of Pennsylvania to be drawn to a scale of 100 feet per inch. The mine workings are platted on the map by laying off, by means of a protractor and a scale, each course of the survey separately, scaling the horizontal distances calculated from the notes of the survey, allowing 1 in. for each 100 ft. of horizontal distance. The map shows the workings as projected on a horizontal plane.

The inclination of the seam is stated on the map; also the tidal elevations of the bottom of each shaft, slope, tunnel, and gangway, and any other point in the mine or on the surface where such elevation is deemed necessary by the inspector. The map also shows the number of the last survey station, and date of the survey in each gangway or advanced working; also the boundary lines of the land, the location of any dams in the mine where water is confined, giving the tidal elevation, inclination of the strata, and area of the workings containing such water.

If the horizontal distance shown on the map between two lifts is 150 ft. and the vertical height 200 ft., the pitch distance between the two lifts is

$$d = \sqrt{150^2+200^2} = 250 \text{ ft.}$$

The average pitch is 200 ft. in 150, or 4 in 3; the tangent of the pitch angle is given by the formula

$$\tan a = 200 \div 150 = 1.33333;$$

or the angle of inclination of the pitch is $a = 53° \ 08'$.

QUES. 57.—If on a pitch of 25° there is a pitch distance of 100 yards between two lifts, what would be the pitch distance if the pitch increased to 55°? *F.—Pa. (A)*

ANS.—The vertical distance between the lifts is obtained by multiplying the pitch distance by the sine of the angle of inclination; thus,

$$d = (100 \times 3) \sin 25° = 300 \times .4226 = 126.78 \text{ ft.}$$

If the pitch increased to 55° the pitch distance corresponding to the same vertical distance between the lifts, is

$$d = 126.78 \div \sin 55° = 126.78 \div .81915 = 154.77 \text{ ft.}$$

QUES. 58.—A counter-gangway is 1,680 feet long on a pitch of 10°; what will be the horizontal distance? *F.—Pa. (A)*

ANS.—The horizontal distance is

$$1{,}680 \times \cos 10° = 1{,}680 \times .9848 = 1{,}654.4 \text{ ft.}$$

QUES. 59.—If a breast is driven up a distance of 450 feet on a pitch of 25°, what is the vertical height of the face above the gangway? *M.—Ill.*

ANS.— $450 \times \sin 25° = 450 \times .42262 = 190.18$ ft.

QUES. 60.—If a breast is driven a distance of 500 feet on a rising grade of 10°, what should be the distance represented on the map of the mine, and what height has the breast attained above the gangway level? *F.—Pa. (A)*

ANS.—The length of the breast shown on the mine map is its horizontal distance, or

$$500 \times \cos 10° = 500 \times .9848 = 492.4 \text{ ft.}$$

The vertical height of the face of this breast above the gangway level is

$$500 \times \sin 10° = 500 \times .1736 = 86.8 \text{ ft.}$$

QUES. 61.—A breast 400 feet long is shown on the mine map as 3.76 inches in length; what is the vertical height of the face above the level of the gangway? *F.—Pa.* (*A*)

ANS.—Assuming the scale of the map to be 100 ft. to the in., the horizontal length of the breast would be $3.76 \times 100 = 376$ ft. The length measured on the pitch being 400 ft., the vertical height or the rise at the face of the breast would be $\sqrt{400^2 - 376^2} = 136.5$ ft. Or, we may first find the pitch angle thus: $376 \div 400 = .94$, the cosine of the pitch angle; hence, the angle is 19° 57′. Then;

$$400 \times \sin 19° 57' = 400 \times .3412 = 136.48 \text{ ft.},$$

length of breast measured on the pitch.

ELEVATIONS AND GRADES IN A MINE

QUES. 62.—If, on examining a mine map, you saw one gangway marked "+532," and another "−413," what would you infer from these figures as to the relative depth from the surface of each gangway? *F.—Pa.* (*A*)

ANS.—These figures refer to the elevation, or vertical heights of the points indicated, above or below an assumed datum plane, which is usually the plane of mean tide water. When the number is preceded by plus (+), the elevation is above datum, but when preceded by minus (−), the elevation is below datum. In this case the difference in elevation of the two gangways is $532 + 413 = 945$ ft. The depth of the lower gangway below the surface is therefore 945 ft. greater than that of the upper gangway. The depth of the higher gangway from the surface is not shown by the data given.

QUES. 63.—The tidal elevation at the head of a shaft is 864 feet, on the rail at the bottom it is 220 feet; what is the depth of the shaft? How much higher is the face of a gangway 1,600 feet long than the foot of the shaft if the tidal elevation at the face is 236 feet? *M.—Ill.*

ANS.—The depth of this shaft is

$$864 - 220 = 644 \text{ ft}$$

The face of the gangway above the foot of the shaft is

$$236 - 220 = 16 \text{ ft.}$$

QUES. 64.—*A*, *B*, and *C* are three points on a gangway, whose elevations are respectively as follows: *A*, 990.10; *B*, 996.60; *C*, 1,000.10. How many feet is *C* higher than *A*? What grade will be obtained from *A* to *C* if the distance is 1,000 feet?

F.—Pa. (*A*)

ANS.—The vertical height of C above A, is

$$1{,}000.10 - 990.10 = 10 \text{ ft.}$$

The grade from A to C will therefore rise 10 ft. in 1,000 ft., or 1 ft. in 100, which corresponds to a grade of 1 per cent.

QUES. 65.—A slope measures 4.6 inches in length on the mine map, the tidal elevation of the top is 780 feet, and of the bottom 530 feet, what is the length and grade of the slope? *F.—Pa. (A)*

ANS.—Assuming that the mine map is drawn to the usual scale of 100 ft. to the in., 4.6 in. on the map corresponds to a distance of

$$4.6 \times 100 = 460 \text{ ft.}$$

This is the horizontal length of the slope.

The rise of the slope is $780 - 530 = 250$ ft. The tangent of the slope angle is then $250 \div 460 = .54348$

and the angle of inclination is therefore 28° 31′; the grade of the slope is 250 ft. in 460 ft., or 1 in 1.84, which is 1 ft. of rise in 1.84 ft. horizontal distance, or 54.3 per cent.

The length of the slope is

$$460 \div \cos 28° \, 31' = 460 \div .87868 = 523.5 \text{ ft.}$$

QUES. 66.—A slope dips 1 foot in each 8 feet for a distance of 504 feet measured on the slope; what is the difference in elevation between the mouth and the face, and what is the horizontal distance between them? *F.—Ia.*

ANS.—The total fall or difference in elevation between the mouth and face of the slope is $504 \div 8 = 63$ ft.

The total horizontal distance is

$$\sqrt{504^2 - 63^2} = 500 + \text{ ft.}$$

QUES. 67.—The tidal elevation of the top of a slope is 900 feet; that of the foot is 760 feet; what is the difference of level between the head and foot of the slope? If the slope is 1,000 feet long what is the grade? *F.—Pa. (A)*

ANS.—The difference of level between the head and foot of the slope is

$$900 - 760 = 140 \text{ ft.}$$

If the slope is 1,000 ft. long, and the total rise 140 ft., the grade is

$$\frac{140}{1{,}000} \times 100 = 14\%.$$

QUES. 68.—Referred to a given datum, the elevation of the surface at A is 276 feet, at B, 305 feet. From bore holes, it is found to be 175 feet to the coal at A, and 190.5 feet at B; what is the difference in the elevation of the seam at these two points, and what is the rise, in feet per hundred, from A to B if the bore holes are 900 feet apart? *F.—Ia.*

ANS.—The elevation of the seam at the two points is as follows:

$$A,\ 276-175 = 101 \text{ ft.}$$
$$B,\ 305-190.5 = 114.5 \text{ ft.}$$

The rise per hundred feet from A to B is, therefore,

$$\frac{114.5-101}{9} = 1.5 \text{ ft.}$$

BORE-HOLE CALCULATIONS

QUES. 69.—Two drill holes, 1 mile apart, are put down to a seam of coal; the depth of the first is 634 feet, and that of the second 850 feet; the surface at the former is 25 feet above the top of the latter. What is the inclination of the coal seam between the two points, measured in inches per yard? *M.—Ill.*

ANS.—Reducing the depths of the two holes to a common level, the corrected depth of the first hole, since the surface there is 25 ft. higher than at the second hole, is $634-25 = 609$ ft. The vertical height that the coal in the first hole is above that in the second is, then,

$$850-609 = 241 \text{ ft., or, } 241\times 12 = 2{,}892 \text{ in.}$$

But, 1 mi. = 5,280 ft., or 1,760 yd. The inclination of the coal, measured in inches per yard, is, therefore,

$$2{,}892 \div 1{,}760 = 1.64 \text{ in. per yd.}$$

QUES. 70.—The accompanying sketch, Fig. 8, represents the relative positions of three bore holes, marked *1*, *2*, and *3*. The proposed position of a shaft is marked on the sketch at *4*. The distance from *1* to *2* is 500 yards, from *2* to *3*, 180 yards, and from *2* to *4*, 320 yards. The line *3* to *4* is at right angles to the line *1* to *2*. A seam of coal is found at a depth of 180 feet at *1*, 260 feet at *2*, and 275 feet at *3*. Assuming a level surface: What will be the depth of the shaft at *4*? How far back on the line *1–2* will you have to go to find the coal at the same depth as at *4*? How far will the line *1–2* require to be prolonged to find the coal at the same depth as at *3*? Find the direction and the amount of dip of the seam. Make a sketch and show the direction of the dip and also of the strike of the seam. *M.—B. C., Canada*

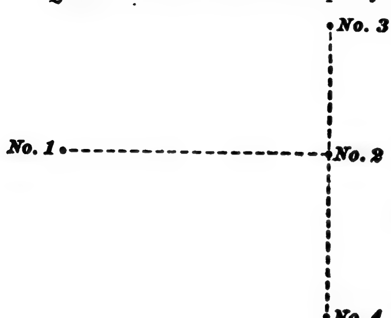


FIG. 8

ANS.—The surface being level, the depths of the several holes show the relative elevations of the seam at each hole, respectively. The seam rises from *3* to *2* a vertical height of $275-260 = 15$ ft. in a horizontal distance of 540 ft. The rise of the seam in this direction is therefore 1 in $\frac{540}{15}$, or 1 in 36. Then, the rise from *2* to *4* in the same direction is $960 \div 36 = 26\frac{2}{3}$ ft., and the depth of the shaft will therefore be

$$260-26\tfrac{2}{3} = 233\tfrac{1}{3} \text{ ft.}$$

The seam rises from *2* to *1* a vertical height of $260-180 = 80$ ft. in a horizontal distance of 1,500 ft. The rise of the seam in this direction is, therefore, 1 in $\frac{1,500}{80}$, or 1 in 18.75. Since the seam rises in the direction *2* to *1* at the rate of 1 ft. in 18.75 ft., it will rise to the level of *4*, or $26\frac{2}{3}$ ft.

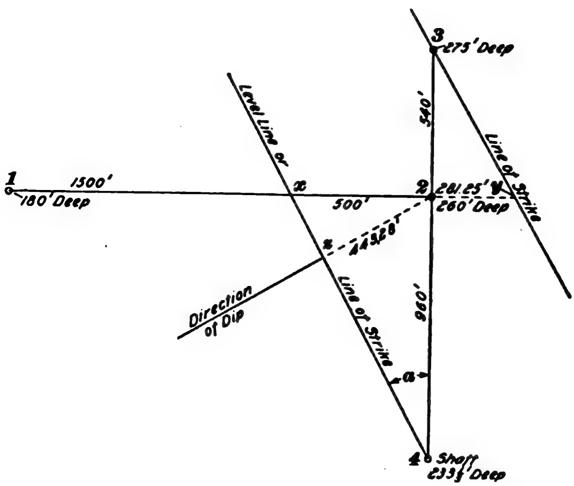


FIG. 9

in going a horizontal distance of $18.75 \times 26\frac{2}{3} = 500$ ft. to a point marked x, Fig. 9.

From *2*, the seam will fall at the same rate in the prolongation of the line *1–2*, and it will therefore fall to the level of *3*, or 15 ft., in going a horizontal distance of $18.75 \times 15 = 281.25$ ft. to a point marked y, Fig. 9.

To find the direction of the dip of the seam or the true dip, first draw the lines $4\,x$ and $3\,y$. Either of these lines are level lines in the seam, and are therefore lines of strike, and are parallel to each other. The direction of the true dip of the seam is a 'ine drawn at right angles to the strike. Hence, if we draw the line $2\,z$ perpendicular to the line $4\,x$, it will represent the direction of the true dip of the seam. To calculate the amount of the true dip of the seam, first find the length of the line $2\,z$; thus, calling the angle $x\,4\,2 = a$, we have

$$\tan a = 500 \div 960 = .52083, \text{ and } a = 27° 30'$$

Then, $2z = 960 \times \sin 27° 30' = 960 \times .46175 = 443.28$ ft.

The seam falls, therefore, $26\frac{2}{3}$ ft. in a horizontal distance of 443.28 ft., and the amount of dip is 1 in $\frac{443.28}{26\frac{2}{3}}$, or 1 in 16.62.

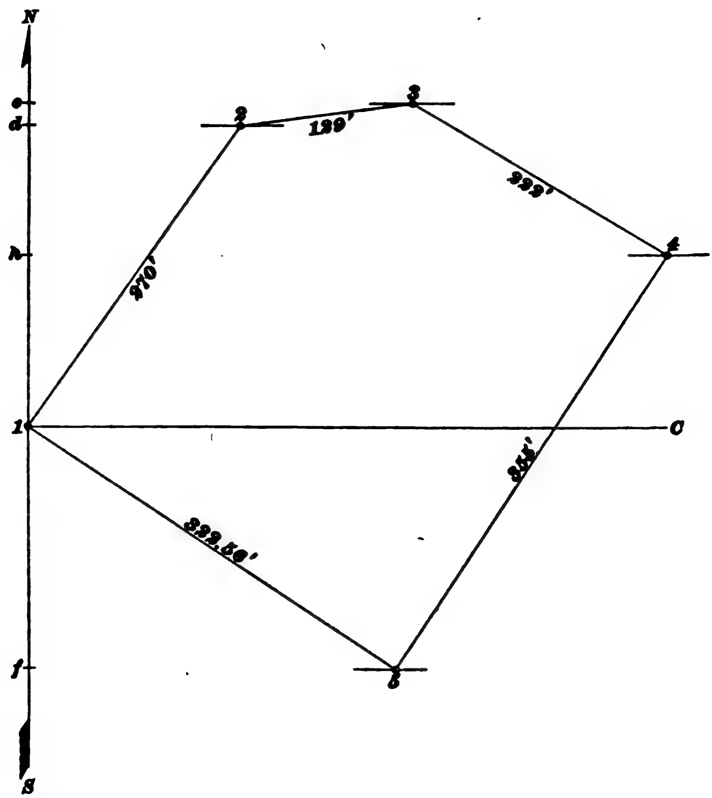


FIG. 10

QUES. 71.—Bore holes are put down to a coal seam at three points, *A*, *B*, and *C*. The depth to the coal at *A* is 250 feet, at *B*, 335 feet, and at *C*, 370 feet. The distance from *A* to *B* is 1,200 feet, from *B* to *C*, 1,550 feet, and from *A* to *C*, 2,250 feet. The surface being level, at what point will the line of strike through *B* cross the line from *A* to *C*? *I.—Ill.*

ANS.—The surface being level, it may be assumed as a plane of reference, say 1,000 ft. above datum. The elevation above datum of the coal at the

bottom of each bore hole is then found by subtracting the depth of each hole from the elevation of the reference plane or surface; thus,

$$A,\ 1{,}000-250 = 750$$
$$B,\ 1{,}000-335 = 665$$
$$C,\ 1{,}000-370 = 630$$

Assuming that the seam is uniform, a line drawn from the bottom of hole A to the bottom of hole C, will lie wholly in the seam, and the problem is now to find a point of this line whose elevation is equal to the elevation of the bottom of hole B (665 ft.). To find the horizontal distance that this point will be from C, find the total rise from C to A ($750-630 = 120$ ft.). The rise from C to B is $665-630 = 35$ ft. Therefore, the distance of the required point from C, being proportional to the rise, is

$$\frac{35}{120}\times 2{,}250 = 656.25 \text{ ft.}$$

PLATTING

QUES. 72.—Plat the following compass survey, to a scale of 100 feet to 1 inch.

STATION	BEARING	DISTANCE IN FEET
1 to 2	N 35° E	270
2 to 3	N 83½° E	129
3 to 4	S 57° E	222
4 to 5	S 34¼° W	355
5 to 1	N 56½° W	322.56

M.—B. C., Canada

ANS.—The accompanying plat, Fig. 10, is reduced to a scale of 142 ft. to 1 in., owing to a lack of space.

QUES. 73.—Make a freehand sketch of the following portion of a survey: A to B, N 30° E, 175 feet; B to C, N 45° E, 150 feet; C to D, N 90° E, 160 feet; and D to E, S 0° 30′ E, 100 feet; using a scale of 1 inch to the foot.

M.—Ill.

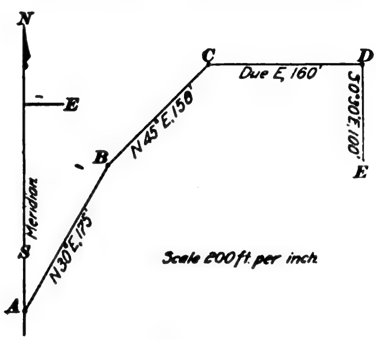


FIG. 11

ANS.—In the accompanying plat, Fig. 11, of the survey we have, for lack of space, used a scale of 200 ft. to the in., instead of 1 ft. to the in., as the question asks, which makes the plat $\frac{1}{200}$ of the size required.

QUES. 74.—Plat the following survey, and calculate its area. Draw a line from the terminal point, to the place of commencement, and give the bearing and distance of the same.

BEARING	DISTANCE IN LINKS
N 13° 33′ W	630
N 30° 42′ E	496
S 74° 00′ E	360
S 40° 00′ E	433
S 65° 00′ W	512

Use a scale of 1 chain to 1 inch.

M.—B. C., Canada

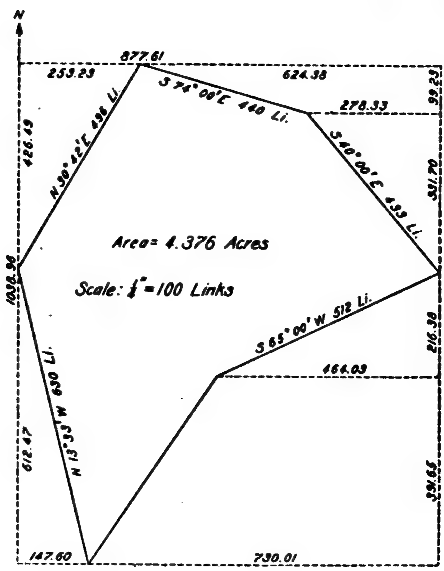


FIG. 12

ANS.—Following is the calculated traverse of the survey, north latitudes being marked +, and south latitudes −; and, likewise, east departures +, and west departures −,

BEARING	DISTANCE IN LINKS	LATITUDES	DEPARTURES
N 13° 33′ W	630	+612.47	−147.60
N 30° 42′ E	496	+426.49	+253.23
S 74° 00′ E	360	− 99.23	+346.05
S 40° 00′ E	433	−331.70	+278.33
S 65° 00′ W	512	−216.38	−464.03
Totals		+1038.96	−611.63
Totals		− 647.31	+877.61
Differences		+ 391.65	+265.98

Fig. 12 is drawn to a scale of 4 ch. to 1 in., for lack of space; this is one-fourth of the required size. To find the bearing of a line drawn from the last point of the survey to the first point of the same, we have

$$265.98 \div 391.65 = .67913 = \tan 34° \ 11', \text{ nearly},$$

and the bearing of this line is S 34° 11′ W. The length of this line is

$$265.98 \div \sin 34° \ 11' = 265.98 \div .56184 = 473.4 \text{ links}$$

The area of this survey is calculated as follows:

		Square Links
Area of circumscribing rectangle $877.61 \times 1{,}038.96$ =		911,801.68
Subtract $\frac{426.49 \times 253.23}{2}$ =	54,000.03	
$\frac{99.23\,(624.38 + 278.33)}{2}$ =	44,787.96	
$\frac{278.33 \times 331.7}{2}$ =	46,161.03	
$\frac{464.03 \times 216.38}{2}$ =	50,203.40	
$\frac{391.65\,(464.03 + 730.01)}{2}$ =	233,822.88	
$\frac{147.6 \times 612.47}{2}$ =	45,200.28	474,175.58
		437,626.10

100 li. = 1 Gunter's ch., and 10 sq. ch. or 100,000 sq. li. = 1 A. Hence, this survey contains 4.376+ A.

Ques. 75.—If the horizontal angles and distances of a survey are as follows:

Course	Bearing	Distance in Feet
1–2	N 37° 13′ E	413.6
2–3	N 10° 56′ E	246.7
3–4	S 17° 23′ E	253.0
4–5	S 43° 37′ E	216.0
5–6	S 33° 43′ W	789.0

how far north or south and east or west of Sta. 1 is Sta. 6? Calculate the course and distance from Sta. 1 to Sta. 6. *M.—B.C., Canada*

Ans.—The traverse of this survey is as follows:

Course	Distance in Feet	Latitudes	Departures
N 37° 13′ E	413.6	+329.37	+250.16
N 10° 56′ E	246.7	+242.22	+ 46.79
S 17° 23′ E	253.0	−241.45	+ 75.59
S 43° 37′ E	216.0	−156.38	+149.00
S 33° 43′ W	789.0	−656.28	−437.97
Totals..........................		+ 571.59	+521.54
Totals..........................		−1,054.11	−437.97
Differences.....................		− 482.52	+ 83.57

In this traverse, north latitudes are marked plus, and south latitudes minus; east departures are marked plus, and west departures minus. Sta. 6 is therefore 482.52 ft. south and 83.57 ft. east of Sta. 1.

To find the bearing of the course from Sta. 1 to Sta. 6, divide the difference in departure by the difference in latitude. Thus, $83.57 \div 482.52 = .17319 = \tan 9° 50'$, which is the angle the course *1–6* makes with the meridian. The bearing of the course is, therefore, S 9° 50′ E. The length of the line *1–6* is found by dividing the difference in departure by the sine of the bearing of the course *1–6*. Thus,

$$83.57 \div \sin 9° 50' = 83.57 \div .1707 = 489.6+ \text{ ft.}$$

PLUMBING A SHAFT

QUES. 76.—How would you carry a transit survey down a perpendicular shaft? *M.—B. C., Canada*

ANS.—Assuming that there is but one shaft that can be used for this purpose, the usual method is to hang two or more heavy plump-bobs in the shaft from points previously located over the mouth of the shaft at the surface. These points have been connected with the surface survey, so as to determine the bearings of the line or lines joining the bobs. The bobs are now lowered to a position close to the bottom of the shaft and allowed to hang free in tubs of water or oil placed there so as to reduce their vibration to a minimum. When the bobs have come to rest sufficiently, a transit set up in the entry at the bottom of the shaft is brought into line with any two of the suspended bobs or plumb-lines. The distance is measured from the transit to one of the bobs, and by referring to the notes of the surface location the bearing of this line passing through the bobs and the transit is obtained, and the exact location of the transit calculated. The mine survey is then extended from this point into the mine, and is thus referred to the same meridian and starting point as the surface survey.

Another method of carrying a surface survey down a perpendicular shaft is by arranging a transit at the shaft head in such a position as to sight down the shaft. A transit for this purpose must be provided with a side or top telescope by means of which a perpendicular line of sight can be had. Two points are thereby established at the foot of the shaft. The line joining these two points and having the same bearing with the surface line is then extended into the mine.

LEVELING

QUES. 77.—Fill in and work out the following levels:

BACKSIGHT	FORESIGHT	DISTANCE IN CHAINS
3.50	4.65	4.60
4.10	10.85	7.80
5.04	9.25	11.60
3.84	12.91	15.20
	7.65 Intermediate sight	
4.12	3.92	21.00
12.96	3.03	27.00

M.—B. C., Canada

ANS.—Assuming a bench-mark elevation of 100 ft. above datum, we have:

Sta.	Backsight	Height of Instrument	Foresight	Elevation
B M				100.00
1	3.50	103.50	4.65	98.85
2	4.10	102.95	10.85	92.10
3	5.04	97.14	9.25	87.89
4	3.84	91.73	12.91	78.82
			7.65	84.08
5	4.12	82.94	3.92	79.02
6	12.96	91.98	3.03	88.95

QUES. 78.—Plat the following notes of a level book:

Backsight	Intermediate Sight	Foresight	Rise	Fall	Reduced Levels	Distance Chains
4.50		6.65				4.60
5.10		11.85				7.80
6.04	10.25					11.60
		13.95				15.20
5.12		8.65				17.00
11.49		4.92				21.00
13.96	7.50					25.00
		4.03				27.00

M.—B C., Canada

Ans.—Assume an elevation of the starting point (Sta. 0) of 100 ft. above datum. Then

Station	Backsight	Rod	Foresight	Rise	Fall	Elevations Feet	Distance Chains
0						100.00	
1	4.50		6.65		2.15	97.85	4.60
2	5.10		11.85		6.75	91.10	7.80
+	6.04	10.25			4.21	86.89	11.60
3			13.95		7.91	83.19	15.20
4	5.12		8.65		3.53	79.66	17.00
5	11.49		4.92	6.57		86.23	21.00
+	13.96	7.50		6.46		92.69	25.00
6			4.03	9.93		96.16	27.00

The line *A B*, Fig. 13, is a reference line at an assumed elevation of 60 ft. above datum. for the purpose of drawing the profile. To construct the

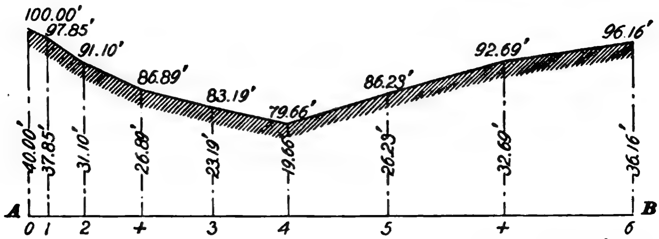


Fig. 13

profile, subtract the elevation of the reference line from the elevation of each station and measure this distance up from the reference line.

LAWS AFFECTING MINE SURVEYS

Ques. 79.—State the requirements of the law with reference to mine maps. *F.—Pa. (A)*

SURVEYS, MAPS, AND PLANS

Ans.—The requirements of the law with reference to mine maps vary somewhat in the different states, but the requirements in the anthracite region of Pennsylvania are probably as rigid as anywhere and are therefore given.

Sec. 1. The owner, operator, or superintendent of every coal mine or colliery shall make, or cause to be made, an accurate map or plan of the workings or excavations of such coal mine or colliery on a scale of 100 feet to the inch, which map or plan shall exhibit the workings or excavations in each and every seam of coal, and the tunnels and passages connecting with such workings or excavations. It shall state in degrees the general

inclination of the strata with any material deflection therein in said workings or excavations, and shall also state the tidal elevations of the bottom of each and every shaft, slope, tunnel, and gangway, and of any other point in the mine or on the surface, where such elevation shall be deemed necessary by the inspector. The map or plan shall show the number of the last survey station and date of each survey on the gangways or the most advanced workings. It shall, also, accurately show the boundary lines of the lands of the said coal mine or colliery, and the proximity of the workings thereto, and in case any mine contains water dammed up in any part thereof it shall be the duty of the owner, operator, or superintendent, to cause the true location of the said dam to be accurately marked on said map or plan, together with the tidal elevation, inclination of strata, and area of said workings containing water; and whenever any workings or excavations are approaching the workings, where such dam or water is contained, or situated, the owner, operator, or superintendent, shall notify the inspector of the same without delay. A true copy of which map or plan the said owner, operator, or superintendent, shall deposit with the inspector of mines for the district in which the said coal mine or colliery is situated, showing the workings of each seam, if so desired by the inspector, on a separate sheet of tracing muslin. One copy of the said map or plan shall be kept at the colliery.

Sec. 2. The said owner, operator, or superintendent shall as often as once in every 6 months, place, or cause to be placed, on the said inspector's map or plan of said coal mine or colliery the plan of the extensions made in such coal mine or colliery during the preceding 6 months. The said extensions shall be placed on the inspector's map, and the map returned to the inspector within 2 months from the date of the last survey.

Sec. 3. When any coal mine or colliery is worked out, preparatory to being abandoned, or when any lift thereof is about to be abandoned, the owner, operator, or superintendent of such coal mine or colliery shall have the maps or plans thereof extended to include all excavations as far as practicable, and such portions thereof as have been worked to the boundary lines of adjoining properties or any part or parts of the workings of which it is intended to be allowed to fill with water, must be surveyed in duplicate and such surveys must practically agree, and certified copies be filed with the inspector of the district in which the mines are situated.

Sec. 4. Whenever the owner, operator, or superintendent of any coal mine or colliery shall neglect or refuse, or from any cause not satisfactory to the inspector, shall fail for a period of 3 months to furnish to the inspector the map or plan of said colliery or of the extensions thereto, as provided for in this act, the inspector is hereby authorized to cause an accurate map or plan of such coal mine or colliery to be made at the expense of the owner thereof, which cost shall be recoverable from said owner as other debts are by law recoverable.

Sec. 5. If the inspector finds or has reason to believe that any map or plan of any coal mine or colliery, furnished under the provisions of this act, is materially inaccurate, it shall be his duty to make application to the Court of Common Pleas of the county in which such colliery is situated, for an order to have an accurate map or plan of said colliery prepared, and if such survey shall prove that the map furnished was materially inaccurate or imperfect, such owner, operator, or superintendent, shall be liable for the expense incurred in making the same.

Sec. 6. If it shall be found that the map or plan furnished by the owner, operator, or superintendent was not materially inaccurate or imperfect, the Commonwealth shall be held liable for the expense incurred in making said test survey.

Sec. 7. If it shall be shown that the said owner, operator, or superintendent has knowingly or designedly caused or allowed such map or plan

when furnished to be incorrect or false, such owner. operator, or superintendent thus offending shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding $500, or imprisonment not exceeding 3 months, at the discretion of the court.

Sec. 8. The maps or plans of the several coal mines or collieries in each district, and which are placed in the custody of the inspector, shall be the property of the Commonwealth, and shall remain in the care of the inspector of the district in which the said collieries are situated, to be transferred by him to his successor in office, and in no case shall a copy of the same be made without the consent of the owner, operator, or superintendent.

Sec. 9. The inspector's map or plan of any particular colliery shall be open for inspection in the presence of the inspector to any miner or miners of that colliery whenever said miner or miners shall have cause to fear that his or their working place or places is becoming dangerous by reason of its proximity to other workings, which may be supposed to contain water or dangerous gases. Said map shall also be open to the inspection and examination of any citizen interested, during business hours.

Sec. 10. It shall be obligatory on the owners of adjoining coal properties to leave, or cause to be left, a pillar of coal in each seam or vein of coal worked by them along the line of adjoining property of such width that, taken in connection with the pillar to be left by the adjoining property owner, will be a sufficient barrier for the safety of the employes of either mine in case the other should be abandoned and allowed to fill with water, such width of pillar to be determined by the engineers of the adjoining property owners, together with the inspector of the district in which the mine is situated, and the surveys of the face of the workings along such pillar shall be made in duplicate and must practically agree. A copy of such duplicate surveys, certified to, must be filed with the owners of the adjoining properties and with the inspector of the district in which the mine or property is situated.

In some states, the ventilating currents must be shown on the map by arrows, and doors, brattices, overcasts, undercasts, etc. indicated.

Ques. 80.—As a mine inspector, what kind of a map would you require from every operator in your district, to comply with the Bituminous Mine Law of Pennsylvania? *I.—Pa. (B)*

Ans.—An accurate map should be made by a competent mining engineer or surveyor, to a scale not smaller than 200 ft. to the in., and showing all measurements in feet or decimal parts of a foot. Also all openings, excavations, shafts, tunnels, slopes, planes, main entries, cross-entries, rooms, etc., opened in said mine; also showing the direction of the ventilating currents in the mine; also showing accurately the boundary lines of said mine, and the relation of the mine to each adjacent mine or workings; also showing the elevation of all tunnels and entries and of the working face adjacent to boundary lines at points not exceeding 300 ft. apart, above mean tide water at Sandy Hook. The map should give the bearings and length of each tunnel or entry, and of each boundary or property line.

Ques. 81.—What is the law in reference to mine maps and escapement shafts in Illinois? *M.—Ill.*

Ans.—The law provides, Section 1, that a map shall be made of every mine, upon a scale, not smaller than 200 ft. to the in., showing the surface

boundary line of the coal rights; and all section or quarter-section lines or corners within the same; the lines of town lots and streets; tracks and side tracks of all railroads; also wagon roads, rivers, streams, ponds, buildings and other landmarks on the surface. The meridian and the scale must be given and the engineer or surveyor must certify upon the map as to the date and accuracy of the survey. The map shall be marked with the name of the mine, the company or owner, and the state, county and township where located. The map of the underground workings must show all shafts, slopes, tunnels, or other openings, all excavations, entries, rooms and cross-cuts; the location of the fan or furnace, and the direction of the air-currents, location of pumps, hauling engines, engine planes, abandoned works, standing water and the boundary line of any outcropping of the seam. A separate map must be made for each separate seam worked. The surface and underground maps must be drawn upon separate sheets, the surface map being drawn upon tracing linen so that it can be superimposed upon the underground plan, to show the relative position of the buildings and surface lines and the underground workings. Each map must show the rise and dip of the seam, from the bottom of the shaft to the face of the workings.

The law provides, Section 3, for the making and maintaining of a second opening or escapement shaft, in every mine, in addition to the hoisting shaft or slope or drift, and allows 3 months for the building of such opening or escapement, for shafts 200 ft. or less in depth; 6 months for shafts more than 200 ft. and less than 500 ft. deep; and 9 months for all other mines, slopes, drifts, or connections with adjacent mines. In all cases, the allotted time dates from the commencement of hoisting coal in the main shaft. The law makes unlawful the employment of more than ten men, in any mine, previous to the completing of such second opening or escapement shaft. The distance between the hoisting shaft and the escapement shall not be less than 300 ft., except with the agreement and consent of the mine inspector of the district, and no inflammable structure, or powder magazine shall be erected between these two shafts.

QUES. 82.—What is the law of Illinois in reference to abandoned mines? *M.—Ill.*

ANS.—The operator of a mine about to be abandoned shall cause a final survey of the mine to be made, and the mine maps extended so as to show all excavations, and the advance face of the workings in their exact relation to the boundary or section lines on the surface.

QUES. 83.—How would you proceed against the owner of a mine in case he was violating the law of Iowa in regard to mine maps? *I.—Ia.*

ANS.—In case the owner or agent of a mine fails to comply with this law within 60 days, the inspector of the district is authorized to cause a map to be made of the mine at the expense of the owner, such expense to be recovered in an action against him by the person doing the work.

CHAPTER II

GEOLOGY AND PROSPECTING

GENERAL DEFINITIONS

QUES. 200.—What is an outcrop?

ANS.—An outcrop is that portion of any bed, seam, or vein that is exposed at the surface or hidden from view by a thin covering of soil or surface wash.

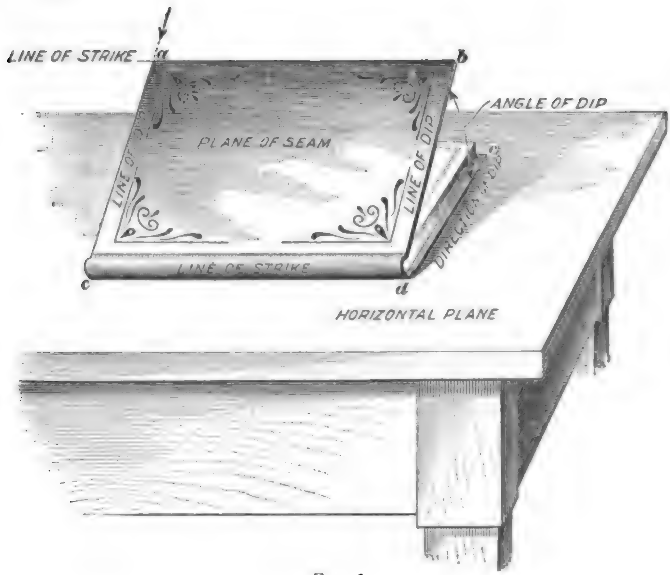


FIG. 1

QUES. 201.—What is meant by the strike and what by the dip of a coal seam? *M.—Ill.*

ANS.—The terms strike and dip in geology are used to describe the position of an inclined seam or stratum. The strike of a seam is the intersection of the seam with a horizontal plane; any level line lying in the plane of an inclined seam represents its strike.

The dip of a seam is its greatest inclination with a horizontal plane.

Fig. 1 illustrates the meaning of these terms: The raised cover of the book represents the plane of an inclined seam, the upper or lower edges of the cover *a b*, *c d*, or any line of the cover parallel to them is a line of strike, while the inclined edges of the cover *a c*, *b d*, or any line of the cover parallel to these lines, is a line of dip; any other line lying in the plane of the cover has an inclination less than the dip of the seam.

Ques. 202.—Describe, by diagram, an anticlinal and a synclinal. *F.—Pa. (A)*

Ans.—Fig. 2 shows examples of anticlines and synclines. When strata are folded or wrinkled the upfolds, or ridges, are called anticlines or anticlinals, and the downfolds, or troughs, are called synclines or synclinals.

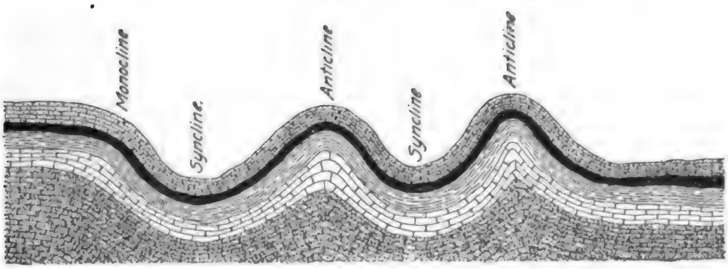


Fig. 2

Ques. 203.—What is a monocline?

Ans.—The term monocline refers to a downward bending from a higher to a lower level as shown in Fig. 2.

Ques. 204.—What distinguishes a stratified from an unstratified rock? *M.—Ill.*

Ans.—A stratified rock gives evidence of having been deposited in layers, and often contains a cleavage along the plane of its deposition; an unstratified rock gives no evidence of being deposited in layers, and contains no cleavages, being massive in its structure throughout.

Ques. 205.—What is meant, in geology, by the terms bed, seam, vein, and dike? *I.—Ill.*

Ans.—The term bed refers strictly to a single layer of a sedimentary deposit. A succession of layers forms a stratum.

A seam is a thin layer or stratum of rock. In coal regions, the terms bed, seam, and stratum are used synonymously, and in many localities the term vein is also wrongly applied in like manner to a bedded deposit.

A vein is a mass of one or more minerals formed by the slow filling of a fissure or cavity, either by replacement, from solution, or other method of deposit.

A dike is a mass of igneous rock filling a fissure in other rocks.

Ques. 206.—What is the difference between a coal seam and a mineral vein? *M.—Ill.*

Ans.—A coal seam is a sedimentary deposit whose plane of stratification indicates the original level of the deposited material. A mineral vein is a fracture or other opening in the strata filled with deposited material. The vein may have any direction with respect to the other strata.

Ques. 207.—What are the structural differences between slate and clod? *M.—Ill.*

Ans.—Each of these is a clay formation. Slate is generally harder and purer than clod, and has a well-defined cleavage in the plane of its deposition. Clod is an impurer, softer clay, having no distinct cleavage in any direction.

Ques. 208.—What forms the most dangerous kind of roof, in coal mining, in this state? *E.—Ill.*

Ans.—The most dangerous kind of roof met with in coal mines in any state is that formed of a hard rock that does not break readily and contains slips. When these slips in the roof strata dip forwards over the coal they are extremely dangerous, since the miner has no knowledge of their presence until the top rock falls.

Ques. 209.—What do we mean when we speak of cleat and cleavage in connection with rock formations? *I.—Ill.*

Ans.—The term cleavage refers to the planes along which the material composing the rock formation tends to split or divide. The cleats of a formation are the joints of cleavage at right angles, or nearly so, to the plane of stratification or deposition. All cleats are planes of cleavage, but all cleavage planes are not cleats. There are two kinds of cleats, face cleats and butt cleats. These are at right angles, or nearly so, to each other, and to the plane of deposition, or bedding plane. The face cleats are distinguished from the butt cleats by being more pronounced. In inclined seams, the face cleats are usually parallel to the strike of the seam, while the butt cleats are parallel, or nearly so, to the dip.

Ques. 210.—What is meant by the terms cleavage, cleat, butts, and ends used in respect to a seam of coal? *M.—Ill.*

Ans.—The term cleavage refers to the plane of division or separation found to a greater or less extent in all sedimentary deposits. The principal cleavage is parallel to the bedding planes or the stratification of the material. The term cleat refers to breaks or joints that are more or less at right angles to the plane of stratification; these are often called joints and are less continuous than the cleavages parallel to the bedding plane. There are often two sets of cleats in coal seams; of these, the more pronounced are usually called face cleats, while the shorter and less pronounced are called butts or ends of the coal. Some coals are practically without cleats and have cleavage parallel to the plane of stratification only; in other coals the cleats or joints are very pronounced.

FAULTS

Ques. 211.—What is meant by a fault? Describe one you have seen? *M.—Ill.*

Ans.—A fault, in geology, is any break in the continuity of strata due to their fracture and displacement. Faulting is accompanied by a displacement of the strata, so that the same strata are not continuous on opposite sides of the fault. The erosion of a portion of a bed and the subsequent filling of the eroded portion with other material does not constitute a fault, there being no displacement of the strata. Such erosions are of frequent occurrence in coal seams and are often, though wrongly, called faults of erosion. A break in a coal seam due to a roll, a horseback, a pinch-out, or some similar cause is likewise often wrongly called a fault.

A fault encountered in a certain coal seam in Colorado gave little previous indication of its presence until suddenly the coal of the seam was replaced by a wall of rock inclined forwards and downwards at an angle of about 60°. A closer examination showed a smooth, shiny surface where the slip had occurred, and the several layers of the seam close to the line of the fault showed a slight inclination in the direction of the slip. The continuation of the seam beyond the fault was found 20 yards below by following the incline downwards.

Ques. 212.—Explain the difference between a fault of erosion and a fault often called a true fault.

Ans.—Correctly speaking, there is no such thing as a fault of erosion. Erosion, in geology, means the eating or wearing away of the material of the rock strata by some natural agency. The conditions that have given rise to the use of this term in coal mining may more properly be described as wants or washouts, since they have been produced by the removal or washing away of a portion of the coal seam, and the deposition in its place of sand or mud that has afterwards been converted into sandstone or shale. A fault, in geology, is any break in the continuity of strata due to their fracture and displacement. Faulting is always accompanied by the relative displacement of the strata so that the same are not continuous on opposite sides of the fault. In the making of faults, there is first a fracture and then a forcible moving up or down of the beds on one side of the fracture; in other words, a downthrow or an upthrow takes place on one or the other side of the fault. The amount of displacement is the amount of faulting that has taken place, and this may vary from less than 1 ft. to more than 10,000 ft.

Ques. 213.—What is a step fault? *M.—Ill.*

Ans.—The term step fault applies to a succession of true faults in which the strata have been broken in several places instead of in one place only. A section of the strata therefore presents an appearance of steps.

QUES. 214.—What is the difference between a horseback and a step fault?

ANS.—A horseback, or hogback as it is sometimes called, is a swell or roll occurring usually in the floor of the seam or underlying strata, and reducing the thickness of the seam, or at times cutting out the seam entirely, but not fracturing or displacing the strata, as occurs always in the case of the step fault. When the horseback rises to the roof so as to cut out the seam entirely, the latter is said to be pinched out, and the occurrence is then called a pinch or pinch-out. A step fault, on the other hand, consists of a series of dislocations that do not nip out the seam, but give it a vertical displacement; consequently, the coal is always found between two or more of the series of faults that produce the steps.

QUES. 215.—Suppose that you encountered a step fault in one of your main entries, the pitch of the fault being from the bottom forwards; where would you expect to find the coal on the other side? *M.—Ill.*

ANS.—The rule in regard to faults is to follow in the direction of the acute angle made by the intersection of the fault line and the plane of the seam, on the side of the fault toward the observer. In this case, the acute angle will be in the roof, since the fault pitches or rises from the bottom forwards. We would expect to find the coal, on the other side of the fault, in the direction following the acute angle referred to, or above.

QUES. 216. What changes in roof, bottom, and coal seam are met with when approaching a fault? What other conditions may be expected? *F.—Ind.*

ANS.—This depends on the character of the fault in question. Proximity to a fault of displacement is frequently indicated by thin spars in the coal, occurring usually in the bedding plane of the seam, and having a trend or inclination in the direction in which the slip has occurred. There is also, frequently a thinning out of the seam, which often assumes an inclination in the direction in which the faulting has taken place. Pinch-outs, horsebacks, etc. are usually indicated by the roof and floor of the seam gradually approaching each other. So-called faults of erosion are often indicated by the presence of stones or boulders in the coal and a gradual thinning of the seam. None of these evidences, however, can be assumed as absolute indications of faults, since they betoken disturbances that may or may not have resulted in the faulting of the strata or erosion of the seam. The local character of each seam must be studied by itself in order to be able to predict, with any accuracy, proximity to a fault. In approaching a fault, a change in the gaseous condition of the mine may often be expected; as, for example, gas or water may often be encountered upon the opposite side of a fault where they have not been found in the present working of the seam; or vice versa these may disappear after crossing a fault.

QUES. 217.—How do clay veins, rock rolls, or other dislocations affect the safety of the men and the economical extraction of the coal; and how would you overcome such difficulties?

F.—Pa. (B)

ANS.—Clay veins often occur in a coal seam in such a manner as to entirely separate the coal. They may also occur in the roof strata forming a line of distinct cleavage. This formation is known to the miner as a slip. The strata, whether coal or roof, when thus divided or crossed by a slip, tend to break along the line of the slip; and, if the existence of the clay vein or slip is unknown to the miner, he may be in danger from a fall of coal, or a fall of roof, as the case may be. When working such coal, or under such roof, sprags should be used, and timbers set close to the face, to insure the safety of the miner while undercutting. A rock roll is a term referring to the coming down of the roof or the rising of the floor in such manner as to partly or wholly cut out the coal. When occurring in the roof, the roll may at times be an element of danger to the miner, as the rock may easily become dislodged and fall. In such cases, care should be used to securely timber the rock. Dislocations of any kind, in the nature of faults, are always expensive, inasmuch as the coal is cut out, and the heading must be continued as day work in foreign matter until the seam is again located. The location of the continuance of the seam beyond the fault is not always an easy matter. The rule for the location of a seam beyond a fault was given in answer to Ques. 216.

FORMATION AND KINDS OF COAL

QUES. 218.—What is a fossil? *M.—Ill.*

ANS.—A fossil is the petrified remains of some organism, either animal or vegetable, or the impression formed in the rock by such organism.

QUES. 219.—What are primary rocks? *M.—Ill.*

ANS.—The term primary was formerly used in geology to include all crystalline rocks, which were thought to be formed before the sedimentary rocks and to be mainly of Archean origin; but this having been disproved the term is not now generally used, although sometimes still used synonymously with Paleozoic.

QUES. 220.—What do you know of the composition of coal, and how is coal supposed to have been formed? *M.—Ill.*

ANS.—Coal is composed of metamorphosed organic matter in the form of carbon, with a greater or less admixture of foreign matter as impurities, such as iron, silica, etc., existing principally as oxides, sulphides, silicates, carbonates, etc. The organic matter forming coal is the accumulation resulting from the successive growth and disintegration of vegetable matter

under water through long ages. This accumulation, becoming submerged by geological changes, was eventually buried beneath successive layers of other materials either deposited from the waters or washed thither by streams. Through the agency of heat and pressure, the organic matter was gradually metamorphosed, forming, first, peat, then lignite, bituminous, and anthracite coals, and graphite, in the order named.

Ques. 221.—Of what does anthracite consist? Give the analysis of a good grade of anthracite. *I.—Pa. (A)*

Ans.—Anthracite consists mainly of fixed carbon, together with small amounts of volatile matter, ash, and sulphur.

An average quality of coal from the northern anthracite field of Pennsylvania contains: fixed carbon, 83.27 per cent.; volatile matter, 4.38 per cent.; moisture, 3.42 per cent.; ash, 8.20 per cent.; sulphur, .73 per cent.

Ques. 222.—What is the difference between anthracite and bituminous coal? *M.—Ill.*

Ans.—Anthracite is harder and contains a larger amount of fixed carbon and a smaller amount of volatile matter; as a consequence, anthracite burns with less smoke and flame. Bituminous coals burn more freely than anthracite, often with a long flame, and they more frequently coke or clinker.

OCCURRENCE OF COAL

Ques. 223.—In which of the great geological divisions are coal beds found? *M.—Ill.*

Ans.—The principal workable coal beds occur in the Carboniferous and Cretaceous formations. To the Triassic belong the important Piedmont, Richmond, and Dan River coals of Virginia and North Carolina. Good beds of Tertiary coal are found in the United States and Canada at different points on the Pacific Coast. The most of the workable beds of coal in Scotland lie in the Subcarboniferous. Beds of Devonian coal are being worked in Northern France, while Silurian coal has been worked in Portugal

Ques. 224.—Are coal seams found anywhere else than among the rocks of the Carboniferous era? *I.—Ill.*

Ans.—Coal seams are also found in the Devonian, Triassic, Jurassic, and Cretaceous eras, and the Tertiary period, overlying the rocks of the Cretaceous era. All the workable seams, however, with but few exceptions, lie in the Carboniferous, Cretaceous, and Tertiary formations.

Ques. 225.—What is meant, in geology, by the Carboniferous measures, and of what materials are these measures principally composed? *M.—Ill.*

Ans.—The term Carboniferous measures refers to the strata deposited during the Carboniferous age. In a more restricted sense, the term is applied to those strata only that belong to the Carboniferous period, and lying between the Subcarboniferous and the Permian periods. These strata contain all the most important coal measures, embracing the coal formations of the Appalachian region and the Central Basin. Besides the coal seams, the principal materials composing these strata are, in the Appalachian region, conglomerates, shales, fireclay, and sandstones, while in the Central Basin limestones and shales predominate. The coal seams are frequently underlaid by a stratum of fireclay.

Ques. 226.—What is meant, in geology, by the Carboniferous system?

Ans.—The Carboniferous system is another name for the Carboniferous period.

Ques. 227.—How are the rocks of the Carboniferous age distinguished from those of, say, the Devonian period? *I.—Ill.*

Ans.—The Carboniferous rocks are distinguished from those of the Devonian by their characteristic fossils and by the order of their superposition in the geological series, the Carboniferous rocks being above the Devonian.

Ques. 228.—Between what two systems of rock formations are the Carboniferous measures found? *I.—Ill.*

Ans.—The measures of the Carboniferous era are underlaid by those of the Devonian era, and overlaid by those of the Triassic. The Carboniferous era consists of three periods, Subcarboniferous, Carboniferous, and Permian. The coal measures of this era are principally found in the Carboniferous period, which is underlaid by the measures of the Subcarboniferous and overlaid by those of the Permian.

PROSPECTING FOR COAL

Ques. 229.—How do we distinguish the various coal seams at points wide apart? *M.—Ill.*

Ans.—They are distinguished by their position in the coal measures; by the similarity of adjacent strata; by the character of the coal forming the seam; the thickness of the bed, and the position of the partings in the bed; and by the presence of certain fossils or impurities either in the coal itself or in the overlying or underlying strata.

Ques. 230.—If you were in search of coal how would you endeavor to find it? *M.—B. C., Canada*

Ans.—In the search for coal, one is guided by the general topography of the surface and the character and geological age of the strata outcropping in different places. A study of the outcropping strata will show whether or not these belong to a coal formation, such as the Carboniferous, Cretaceous, or Tertiary, and a judgment on the probable occurrence of coal in them should be based on a familiar knowledge of the geology of the section. For example, the coals of the Central Basin and the Appalachian system in America are Carboniferous, while the coals of the Pacific slope and the Northwestern Territory of Canada are mostly Cretaceous or Tertiary. Such characteristic surface features as indicate proximity to coal beds should be carefully noted. Among these may be mentioned any form of coal blossom, as coloration of the soil or water draining from the underlying beds, or small particles of disintegrated coal found in the wash of the streams, or the presence of any of the well-known fossils of the coal formations. When it has been determined that the strata belong to the coal formations an attempt should be made to locate the workable beds of coal by prospect ditches dug across the supposed position of the outcrop, or by borings. Prospect ditches are usually open cuts made in steps, one above the other, on a hillside or surface slope, in such manner as to expose the true position of the underlying beds whose outcroppings have been covered by the surface soil.

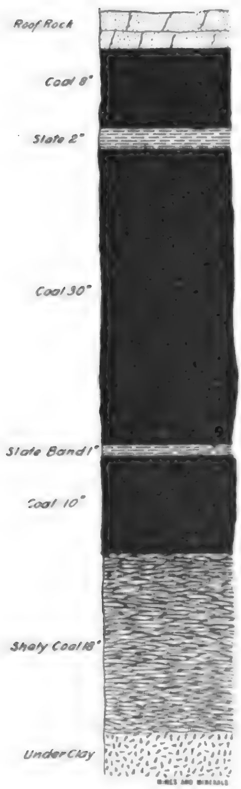


Fig. 3

Ques. 231.—Describe the various methods of boring for coal. *M.—B. C., Canada*

Ans.—Shallow borings are often made with a common fence auger through the overlying soil or drift. Hand drills are sometimes used, operated by gearing, to depths varying from 100 to 300 ft. in some strata. Two general types of drills are used. Percussive drills that chip and break the rock at the bottom of the hole by successive blows of the drill; to this class belong the ordinary hand churn drill, the spring-pole, or jumper, drill operated by hand, and the various forms of percussive power drills operated by compressed air. The second class includes the various forms of rotary drills operated both by hand and by steam, compressed air, or electricity. In this class are comprised diamond core drills that cut out a cylindrical core from the center of the hole, thereby affording a sample of the strata passed through.

GEOLOGICAL SECTIONS

Ques. 232.—Make a sketch of the coal face of the seam you are working in, showing the different partings, noting their thickness, and designating whether they are slate, dirt, coal, or clay.

F_1.—Ala.

Ans.—The section, Fig. 3, is an average section of a seam and shows the method of sketching a coal seam.

Ques. 233.—How many seams of coal are there in the mine in which you are employed? Give the local name of each.

F.—Pa. (A)

Ans.—A generalized section through the measures contained within the limits of this inspection district (first anthracite, near Carbondale, Pennsylvania) shows eleven seams, named as follows: the 8-foot vein or Olyphant No. 1; 5-foot vein, or Olyphant No. 2; 4-foot vein, sometimes called the 3-foot vein; diamond vein; rock vein; 14-foot vein, or big vein; new county vein; Clark vein; No. 1 Dunmore vein; No. 2 Dunmore vein; and No. 3 Dunmore vein.

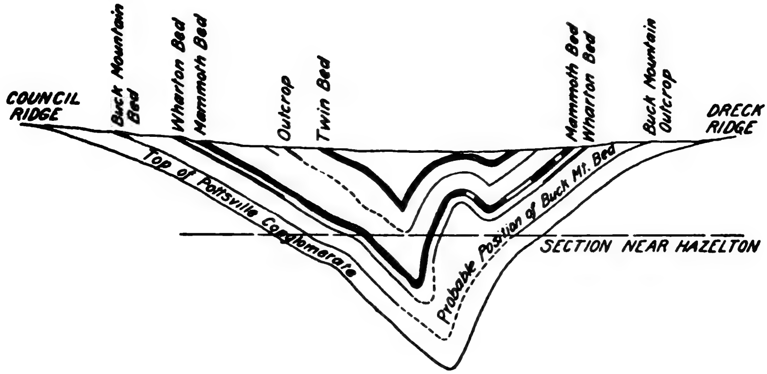


Fig. 4

Ques. 234.—Draw a geological cross-section from north to south through an anthracite field, at any point with which you are familiar, placing upon it the workable coal beds.

I.—Pa.(A)

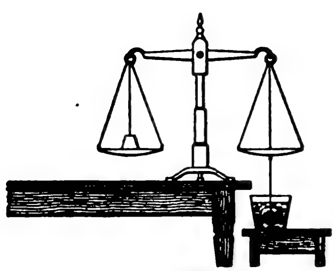
Ans.—This question is of strictly local interest, but the accompanying section, Fig. 4, from the Pennsylvania Geological Reports shows how to sketch such a section as is asked for.

QUES. 235.—Describe, in a general way, the principal characteristics of the Illinois coal field. *I.—Ill.*

ANS.—The Illinois coal field forms a portion of the great Central coal field, covering a considerable portion of Illinois, Indiana, and Western Kentucky, etc. There are about 36,000 square miles of coal-bearing territory in Illinois. Sixteen workable seams are enumerated by the State Geological Survey, but only one of these, the No. 6, has been developed to any extent. This seam lies at an average depth of 250 feet below the general surface, and, where it is worked, varies in thickness from 4 to 7 feet. The coal is of moderate hardness, an underclay forming the floor or thill of the seam, while the roof varies in different localities from shale and lime rock to sandstone and conglomerate, the former being most general. The coal does not form a continuous seam of uniform thickness, but occurs in numerous shallow local basins, more or less separated by faults, pinch-outs, horsebacks, etc. The seam, in general, has but little inclination, but the general dip of the Illinois coal measures is from N W to S E, rising afterwards to the south and west. Seam No. 5 is also worked at some points in the state and there is a difference of opinion among Illinois mining men as to the identification of seams No. 5 and No. 6. This difference can be settled only by a study of the fossils in the two seams, which has not yet been made.

CONTENTS OF COAL SEAMS

QUES. 236.—Explain the meaning of the term specific gravity, and state how you would determine the specific gravity of coal. *M.—B. C., Canada*



MINES AND MINERALS.
FIG. 5

ANS.—The specific gravity of a body is the relative weight of that body as compared with the weight of an equal volume of a given standard. The usual standard for solids and liquids is water, while that for gases is air. To find the specific gravity of a piece of coal, first find the exact weight W of the coal on a sensitive balance, then ascertain its weight w when suspended in water by a horsehair, from one end of the balance beam, as shown in Fig. 5. The difference $(W-w)$ between these two weights is the buoyancy of the water and is the weight of the water displaced or the weight of an equal volume of water. The ratio of the weight of the coal to the weight of an equal volume of water is the specific gravity of the coal. Thus,

$$\text{sp. gr.} = \frac{W}{W-w}$$

QUES. 237.—A piece of coal weighs 960 grains in air and 164 grains in water; what is the specific gravity of the coal? *I.—Pa. (B)*

ANS.— $$\text{sp. gr.} = \frac{W}{W-w}$$

in which W = weight of body in air;
w = weight of body in water.

Substituting the given values in the formula,

$$\text{sp. gr.} = \frac{960}{960-164} = 1.206$$

QUES. 238.—What is the weight of 1 cu. yd. of coal, the specific gravity of which is 1.4? *M.—Ill.*

ANS.—Since 1 cu. ft. of water weighs 62.5 lb.,

$$\frac{62.5 \times 27 \times 1.4}{2,000} = 1.18+ \text{ short tons}$$

NOTE.—The short ton (2,000 pounds) is generally used in bituminous-coal calculations and the long ton (2,240 pounds) in anthracite calculations.

QUES. 239.—How many tons of anthracite are there under a lot 150 feet by 500 feet, the vein being 3 feet thick, assuming the coal to weigh 93 pounds per cubic foot? *F.—Pa. (A)*

ANS.— $$\frac{150 \times 500 \times 3 \times 93}{2,240} = 9,341.5+ \text{ long tons}$$

QUES. 240.—A square field of 32,400 square yards area overlies a seam of coal 4 feet thick, pitching at an angle equal to 1 foot vertical in 6 feet horizontal; what is the total weight of coal in this field, if its specific gravity is 1.28? *M.—B. C., Canada*

ANS.—The given area of the field is a horizontal area and must be divided by the cosine of the angle of inclination of the seam to obtain the corresponding area in the seam. The tangent of the angle of inclination in this case is $\frac{1}{6}$ = .1667, and the angle of inclination is, therefore, 9° 28′. Hence, for the corresponding area in the seam,

$$\frac{32,400 \times 9}{\cos 9° 28'} = \frac{32,400 \times 9}{98638} = 295,633+ \text{ sq. ft.}$$

Multiplying this area by the thickness of the seam, and the weight of 1 cu. ft. of water, and the specific gravity of the coal, to obtain the actual weight of coal in this field, we have

$$\frac{295,633 \times 4 \times 62.5 \times 1.28}{2,000} = 47,301+ \text{ short tons}$$

QUES. 241.—How many tons of coal underlie a square field containing 5 acres, the seam being 6 feet thick and lying at an angle of 15°, the specific gravity being 1.325? *I.—Ia.*

Ans.—The inclined area of the seam corresponding to a horizontal area of 5 A. is in this case,

$$\frac{5\times 43{,}560}{\cos 15^\circ} = \frac{217{,}800}{.96593} = 225{,}482 \text{ sq. ft.}$$

The cubic contents of the seam are then,

$$225{,}482\times 6 = 1{,}352{,}892 \text{ cu. ft.}$$

$$\frac{1{,}352{,}892\times 62.5\times 1.325}{2{,}000} = 56{,}018 \text{ short tons}$$

Ques. 242.—How many tons of coal are there underlying a square field containing 4 acres, the seam being 4 feet 4 inches thick, lying at an angle of 31°, the specific gravity of this coal being 1.51? *M.—B. C., Canada*

Ans.—There being 43,560 sq. ft. in 1 A. of level ground, the number of cubic feet of coal in a seam 4 ft. 4 in. thick, having an inclination of 31° and underlying 4 A. of land is

$$4\times\frac{43{,}560\times 4\tfrac{1}{3}}{\cos 31^\circ} = \frac{755{,}040}{.85717} = 880{,}852 \text{ cu. ft.}$$

Since the specific gravity of the coal in this case is 1.51, its weight, in tons, is,

$$\frac{880{,}852\times 62.5\times 1.51}{2{,}000} = 41{,}565.2 \text{ short tons}$$

Ques. 243.—We have bought a piece of coal land, commencing at the southeast corner of the northwest quarter of Section 24 and running due west 2,640 feet, thence north 2,640 feet, thence east 2,400 feet, thence to the place of beginning; how many tons of coal are there underlying this land, allowing 27 cubic feet to a ton? The coal is 4.5 feet thick; allow 36 per cent. for screening and 6 per cent. waste. *M.—Ill.*

Ans.—This piece of land lies in the form of a trapezoid having the north and south sides parallel; these sides are 2,400 ft. and 2,640 ft. in length, respectively, and 2,640 ft. apart. The area of the piece is, therefore,

$$2{,}640\times\frac{(2{,}400+2{,}640)}{2} = 6{,}652{,}800 \text{ sq. ft.}$$

Allowing for a total loss of $36+6 = 42$ per cent., there is mined $100-42 = 58$ per cent. of the coal; and allowing 27 cu. ft. to a ton, the total weight of coal mined from this land is

$$\frac{6{,}652{,}800\times 4.5\times .58}{27} = 643{,}104 \text{ T.}$$

The land contains

$$6{,}652{,}800\div 43{,}560 = 152.73 \text{ A., nearly;}$$

and the tonnage per acre is, therefore,

$$643{,}104\div 152.73 = 4{,}210+ \text{ T.}$$

A common rule in estimating the net tonnage of coal per acre is to allow 1,000 T. per A. for each foot of thickness of the seam, which in this case would be $1,000 \times 4.5 = 4,500$ T. per A., which closely approximates the result obtained in this case.

QUES. 244.—A breast is driven 150 feet in length, 24 feet in width, and the thickness of the seam is 10 feet; how many tons of anthracite should the breast yield after deducting two-tenths of the cubic contents for refuse, assuming that 1 cubic yard of anthracite weighs 1 long ton? *I.—Pa. (A)*

ANS.—The excavation in this breast is,

$$\frac{150 \times 24 \times 10}{27} = 1,333\tfrac{1}{3} \text{ cu. yd. or T.}$$

Allowing a loss of two-tenths as refuse, the total output of coal from the breast is,

$$1,333\tfrac{1}{3} \times .8 = 1,066\tfrac{2}{3} \text{ long tons}$$

QUES. 245.—A room is driven 300 feet in length, 27 feet in width. The thickness of the coal seam is $3\frac{1}{2}$ feet; how many tons of bituminous coal should the room yield, after deducting 10 per cent. for refuse, assuming that 1 cubic yard of bituminous coal weighs 1 short ton? *F.—Pa. (B)*

ANS.—Under the conditions named, the weight of coal taken from this room would be

$$\frac{.9(300 \times 27 \times 3.5)}{27} = 945 \text{ short tons}$$

QUES. 246.—The distance between a pair of cross-entries is 500 feet; from the main entry out to the boundary line is 1,000 feet; the thickness of the seam is $6\frac{1}{2}$ feet; and the wastage in slack and dirt is 15 per cent. The specific gravity of the whole seam is 1.3. How many tons of coal can be got from this block, 25 per cent. being left for pillars? *M.—Ill.*

ANS.—The weight of coal in the entire block is equal to

$$\frac{500 \times 1,000 \times 6.5 \times 62.5 \times 1.3}{2,000} = 132,031+ \text{ short tons}$$

The weight of material that may be taken out is $100-25 = 75$ per cent. of the entire cubic contents of the block, or

$$132,031 \times .75 = 99,023+ \text{ short tons}$$

The waste being 15 per cent., the weight of clean coal is $100-15 = 85$ per cent. of this amount, or

$$99,023 \times .85 = 84,169+ \text{ short tons}$$

Ques. 247.—What is the estimated tonnage per acre per foot of thickness for bituminous coal? F_1.—*Ala.*

Ans.—The amount of bituminous coal that may be obtained from any given seam is usually estimated at 100 T. per A. per in. in thickness of vein; this would make 1,200 T. per A. per ft. of thickness; but, with careful mining this can often be increased under ordinary conditions.

CHAPTER III

MINE GASES

COMPOSITION AND WEIGHT OF ATMOSPHERIC AIR

QUES. 300.—Of what is atmospheric air composed?

M.—B. C., Canada

ANS.—Atmospheric air is composed of nitrogen and oxygen gases in the proportion of 79.3 volumes of nitrogen to 20.7 volumes of oxygen, or practically, 4 volumes of nitrogen to 1 of oxygen. There are always traces of carbonic-acid gas, ammonia gas, and moisture in the atmosphere.

QUES. 301.—Find the weight of 1 cubic foot of air at 60° F., barometer 30 inches. *F.—Pa. (A)*

ANS.—The weight of 1 cu. ft. of air at an absolute temperature of 1° F., and under a barometric pressure of 1 in., is 1.3273 lb. Since the volume of any given weight of air increases directly as the absolute temperature, and inversely as the pressure, the weight of air per unit of volume varies directly as the pressure and inversely as the absolute temperature. For this reason, the weight of 1 cu. ft. of air at unit pressure and temperature, is multiplied by the actual pressure and divided by the actual absolute temperature to obtain the weight of the same air at such pressure and temperature. This gives the following formula:

$$w = \frac{1.3273 \times B}{460+t}$$

in which w = weight of 1 cu. ft. of air at pressure B, and temperature t, in pounds;

B = barometric pressure, in inches of mercury;

t = common temperature, in degrees Fahrenheit;

$460+t$ = absolute temperature, in degrees Fahrenheit.

Substituting the given values in this equation,

$$w = \frac{1.3273 \times 30}{460+60} = .0766 \text{ lb., nearly}$$

QUES. 302.—With a temperature of 32° F., what is the weight of a cubic foot of air when the barometer reads 29.2 inches?

I.—Pa. (B)

Ans.—Substituting the given values in the formula, $w = \frac{1.3273 \times B}{460 + t}$; the required weight of 1 cu. ft. of air, at this temperature and pressure, is

$$w = \frac{1.3273 \times 29.2}{460 + 32} = .0787 + \text{ lb.}$$

Ques. 303.—If 13 cubic feet of air at an ordinary temperature and pressure weigh 1 pound, how many tons of air pass through a mine in 8 hours where the current measures 52,000 cubic feet per minute? *E.—Ill.*

Ans.— $$\frac{52{,}000 \times 60 \times 8}{13 \times 2{,}000} = 960 \text{ short tons}$$

SPECIFIC GRAVITY OF GASES

Ques. 304.—What is meant by the specific gravity of mine gases? *I.—Pa. (B)*

Ans.—The specific gravity of a gas is its density, referred to air as a standard. It is the ratio between the weight of any given volume of gas and the weight of an equal volume of air at the same temperature and pressure.

Ques. 305.—What relation has whitedamp to air as regards specific gravity? *F_1.—Ala.*

Ans.—Whitedamp is another name for carbon monoxide, CO; it is lighter than air, its specific gravity being .967.

Ques. 306.—Name a gas commonly found in mines that is heavier than air, and also one that is lighter than air. *F.—Pa. (A)*

Ans.—Carbon dioxide or blackdamp, CO_2, and hydrogen sulphide or stinkdamp, H_2S, are both heavier than air. Marsh gas, or light carbureted hydrogen, CH_4, and carbon monoxide or whitedamp, CO, are both lighter than air.

Ques. 307.—Which is the more dense, carbon dioxide or marsh gas, and why? *B.—B. C., Canada*

Ans.—Carbon dioxide is more dense than marsh gas, because it contains a greater weight of matter per unit of volume. This is shown by the molecular weights of the two gases, that of CO_2 being 44, and that of CH_4, 16. The densities of these gases are to each other, therefore, as 44 : 16 or 11 : 4; that is to say, carbon dioxide is $\frac{11}{4} = 2\frac{3}{4}$ times as heavy as marsh gas, volume for volume.

SOLUBILITY OF GASES

QUES. 308.—To what extent is air soluble in water at ordinary temperatures and pressures? *I.—Pa. (A)*

ANS.—To the extent of 1.78 per cent.; that is to say, 100 volumes of water will absorb 1.78 volumes of air at ordinary temperature and pressure.

QUES. 309.—To what extent are the following gases soluble in water: carbon dioxide, hydrogen sulphide, and marsh gas? *I.—Pa. (B)*

ANS.—The solubility of these gases at the ordinary temperature and pressure is about as follows: carbon dioxide, 100 per cent.; hydrogen sulphide, 300 per cent.; marsh gas, 5 per cent.; that is to say, at a temperature of 60° F. and a barometric pressure of 30 in., water will absorb its own volume of carbon dioxide, or three times its volume of hydrogen sulphide, or one-twentieth of its volume of marsh gas.

COMPOSITION AND PROPERTIES OF MINE GASES

QUES. 310.—Explain the symbols CH_4, CO_2, SH_2, and what are their comparative weights. *F.—Pa. (A)*

ANS.—The symbol CH_4 represents one molecule of light carbureted hydrogen or marsh gas. A molecule of this gas consists of one atom of carbon chemically united with four atoms of hydrogen. The one atom of carbon is represented by the symbol C, and the four atoms of hydrogen by the symbol H_4, the number of atoms being indicated by the small subscript figure following the symbol; the absence of a number indicates a single atom only.

The symbol CO_2 represents one molecule of carbon dioxide (carbonic-acid gas). A molecule of this gas consists of one atom of carbon chemically united to two atoms of oxygen. The one atom of carbon is represented by the symbol C, and the two atoms of oxygen by the symbol O_2.

The symbol SH_2, or as it is more usually written, H_2S, stands for hydrogen sulphide (sulphureted-hydrogen gas). A molecule of this gas consists of two atoms of hydrogen chemically united with one atom of sulphur; the symbol of sulphur being S.

The molecular or comparative weights of these gases are obtained by adding together the atomic weights of the atoms forming each molecule; thus,

$$CH_4,\ 12+(4\times 1) = 16$$
$$CO_2,\ 12+(2\times 16) = 44$$
$$H_2S,\ (2\times 1)+32 = 34$$

QUES. 311.—Give the names, chemical symbols, and composition of the different gases met with in coal mines.

ANS.—The gases commonly met with in coal mines are the following:

Carbureted hydrogen or marsh gas, CH_4; a molecule of this gas consists of one atom of carbon combined with four atoms of hydrogen.

Carbon monoxide (carbonic-oxide gas, or whitedamp), CO; a molecule of this gas consists of one atom of carbon combined with one atom of oxygen.

The compound CO was formerly known as carbonic oxide, but this name does not describe the compound and does not agree with the naming of compounds as now used by chemists. The term carbonic oxide has therefore been given up universally in chemical literature and is rapidly being done away with in all scientific and technical literature; the term carbon monoxide has been substituted for it. This name means that one atom of carbon is combined with one atom of oxygen.

Carbon dioxide (carbonic-acid gas, blackdamp, or chokedamp) CO_2; a molecule of this gas consists of one atom of carbon combined with two atoms of oxygen.

The compound CO_2 was formerly called carbonic acid, but this name has also been given up, for a similar reason, in scientific and technical literature and the term carbon dioxide substituted. This term means that one atom of carbon is combined with two atoms of oxygen. The modern terms will be used in this book, although the chemical symbols will sometimes be given in parentheses to avoid confusion, as the older terms are used in much of the older mining literature and many of the mine examining boards still adhere to them.

Hydrogen sulphide (sulphureted hydrogen or stinkdamp), H_2S; a molecule of this gas consists of two atoms of hydrogen combined with one atom of sulphur.

Olefiant gas (ethane or ethylene), C_2H_4; a molecule of this gas consists of two atoms of carbon and four of hydrogen.

Nitrogen, N; this is a simple gas.

Oxygen, O; this is a simple gas.

Hydrogen, H; this is a simple gas.

QUES. 312.—Name and describe the different gases common to the anthracite mines. What are their dangers to life, and their injurious effects on the workmen employed therein? Give also their symbols, specific gravities, and properties. Where are they found? How produced? State their effects on combustion. *I.—Pa. (A)*

ANS.—Carbureted hydrogen, or marsh gas, CH_4, is produced by the metamorphism of the carbonaceous matter forming coal, when this has taken place with the exclusion of air and in presence of water. It is a colorless, odorless, and tasteless gas having a specific gravity of .559. It diffuses rapidly in the air, forming a firedamp mixture. Marsh gas is combustible, burning with a blue flame, but will not support combustion. Mixed with air in certain proportions, it forms an explosive mixture (firedamp). The gas is not poisonous, and when mixed with air in sufficient proportion, the mixture may be breathed with impunity for a considerable time, producing only a slight giddiness that passes off on return to fresh air. Pure marsh gas will not support life but suffocates by excluding oxygen from the lungs. The gas being lighter than air accumulates in the

roof and higher portions of the mine workings. The gas is detected by observing its effect on the flame of a safety lamp; it produces an almost non-luminous flame cap that increases in height as the percentage of gas is increased.

Olefiant gas, C_2H_4, and ethane, C_2H_6, are heavy hydrocarbons produced in a similar manner to marsh gas, but they contain a larger percentage of carbon. These gases, when present in a firedamp mixture, lower the temperature of ignition and render the firedamp more dangerous; they form the illuminating principle of coal gas. The specific gravity of olefiant gas is .97, and that of ethane 1.048. The other properties of these gases are similar to those of marsh gas.

Carbon monoxide, CO, often called whitedamp, is produced by the incomplete combustion of carbonaceous matter. It is one of the chief products of gob fires, and is also produced largely in the explosion of blasting powder or firedamp, where the supply of air is insufficient for the complete combustion of the carbon. It is a colorless, odorless, and tasteless gas, having a specific gravity of .967. It is combustible, burning with a pale blue flame. This gas also supports combustion, lamps burning more brightly in the gas than in air. It has the widest explosive range of any gas commonly found in coal mines except hydrogen. Its effect, when present in a firedamp mixture, is to widen the explosive range of the firedamp. It is a very poisonous gas, absorbing oxygen from the blood. It acts on the human system as a narcotic, producing drowsiness or stupor followed by acute pains in the head, back, and limbs, and afterwards by delirium and death. The gas being lighter than air, accumulates in the roof and upper portions of mine workings. This gas is detected by its effect on the flame of a lamp. The gas causes the lamp to burn more brightly and the flame reaches upward in a slim, quivering taper.

Carbon dioxide, CO_2, often called blackdamp or chokedamp, is produced by the complete combustion of carbonaceous matter, whether slow or rapid, in a plentiful supply of air. This gas is also produced by the breathing of men and animals, the burning of lamps, and is a later product of all explosions of powder and gas. It is also often largely carried in solution by the mine water and escapes when this water evaporates into the air. It is a colorless, odorless, and tasteless gas, having a specific gravity of 1.5291. This gas is not combustible and does not support combustion. When present in small quantities, this gas diminishes the flame of a lamp; when larger quantities are present, the flame is extinguished. This gas is detected by its effect upon the flame of a lamp. The gas diffuses slowly into the atmosphere. It is not poisonous but suffocates by excluding oxygen from the lungs. When breathed for any length of time, headache and nausea are produced, followed by pains and weakness in back and limbs; larger quantities of the gas cause death by suffocation. This gas when present in firedamp mixtures narrows the explosive range of the firedamp. If to a firedamp mixture at its most explosive point, one-seventh of its volume of carbon dioxide is added, the resulting mixture is rendered inexplosive. The gas is heavier than air and accumulates at the floor and in the lower mine workings.

Hydrogen sulphide, $H_2 S$, is produced in the mine by the disintegration of iron pyrites in the presence of moisture. It is a colorless and tasteless gas, but possesses a strong odor resembling that of rotten eggs, on which account it is often called stinkdamp. Its specific gravity is 1.1912. This gas is combustible, but like marsh gas, when pure, will not support combustion. When mixed with about seven times its volume of air, the gas is violently explosive. It is extremely poisonous, acting to derange the system when breathed in small quantities, and producing unconsciousness and prostration when a larger amount of the gas is present. The gas is heavier than air and accumulates at the floor and in the lower mine workings. It is detected by its smell.

Nitrogen, N, occurs both occluded in the coal and as the principal constituent of the air, of which it forms about 80 per cent. by volume or 75 per cent. by weight. It is colorless, odorless, tasteless, and has a specific gravity of .971. It is not combustible and will not support combustion. It is not poisonous, but suffocates, in the same way as carbon dioxide, by excluding oxygen from the lungs. As nitrogen is lighter than air, it will be found at the roof, if present alone in quantity. It is very similar in its action and properties to carbon dioxide, and is distinguished from carbon dioxide chiefly by being lighter than air, while carbon dioxide is heavier than air. Its effect on the flame of a lamp is to dim it, and to extinguish it if present in a sufficient quantity.

Oxygen, O, occurs in small quantities in the coal and forms about one-fifth of the atmosphere by volume. It is colorless, odorless, tasteless, and has a specific gravity of 1.106. It is not poisonous, and produces an exhilirating effect on the system if present in excess in the atmosphere. It supports combustion.

Hydrogen, H; free hydrogen occurs rarely in mine gases, although it is sometimes found occluded in the coal. It is colorless, odorless, and tasteless, and has a specific gravity of .069. It is highly explosive and is combustible. It diffuses very rapidly in the air and is, therefore, seldom found in quantity in a mine.

QUES. 313.—Name and describe the different gases common to the coal mines of the bituminous region of Pennsylvania. What are the dangers to life and injurious effects of these gases on the health of the workmen employed in said mines? Give the symbols, specific gravities, and properties of the gases. Where are they found, and how produced? State their effects on combustion.

I.—Pa. (B)

ANS.—This question has been answered in reply to Ques. 312, as the gases met with in bituminous mines are exactly the same as in anthracite mines.

QUES. 314.—What noxious gases are produced by fires and explosions of firedamp in mines? *F.—Pa. (B)*

ANS.—Carbon monoxide, CO, and carbon dioxide, CO_2, and sometimes traces of sulphurous-acid gas, SO_2. Nitrogen is usually found in afterdamp, but is not produced by the fire or explosion producing the afterdamp. It is merely the nitrogen of the atmosphere, remaining after the oxygen has been burned out.

QUES. 315.—Give the names, symbols, properties, atomic weights, specific gravities, and general characteristics of the inexplosive gases found in coal mines. Where are they found, how generated, and how can they be removed or rendered harmless?
F.—Pa. (B)

ANS.—The inexplosive gases found in coal mines are nitrogen and carbon dioxide. The symbol of nitrogen is N, atomic weight 14, specific gravity referred to air .9713. This gas is usually found in large proportion in the afterdamp of a mine explosion; it has played no part in the explosion, but remains when the oxygen has been burned out of the air. Nitrogen is a particularly inert gas, is not combustible, and does not support combustion. It is not poisonous, but suffocates by excluding oxygen from the lungs.

Carbon dioxide, or blackdamp, often called chokedamp, is expressed by the symbol CO_2; its molecular weight is 44, its specific gravity, referred to air, 1.529. This gas is the result of the complete combustion of carbonaceous matter in a free supply of air; it is formed by the breathing of men and animals, the burning of lamps, and is a product of any form of combustion in the mine where a plentiful supply of air is at hand. It is not combustible and does not support combustion; it is not poisonous, but suffocates by excluding oxygen from the lungs. Its effect is first to cause headache, nausea, and pain in the back and limbs, followed by suffocation and death. Both of these gases are best removed by a large air-current.

QUES 316.—Name the non-combustible gases, and describe the conditions under which these gases may be found in mines.
F.—Pa. (B)

ANS.—The non-combustible mine gases are the same as the inexplosive gases mentioned in the answer to Ques. 315, namely, nitrogen, N, and carbon dioxide, CO_2. The conditions under which these gases occur in mines are described in the same answer.

QUES. 317.—Name and describe the explosive gases found in coal mines, giving their names, symbols, specific gravities, properties, and general characteristics. Where are they found, and how can they be eliminated from the mines? *B.—Pa. (B)*

ANS.—The explosive gases of coal mines are marsh gas, carbon monoxide, and hydrogen sulphide. These gases have been described fully in the answer to Ques. 312. Gas is not always found in quantity in that portion

of the mine where it is being generated; the lighter gases, marsh gas and carbon monoxide, owing to their low specific gravity, tend to rise and therefore accumulate at the roof and the higher portions of the mine workings, while hydrogen sulphide, which has a specific gravity greater than that of air, accumulates near the floor and in the lower portions of the workings. In order to remove mine gases from the workings, it is necessary to maintain a current of a sufficient velocity to sweep them from the cavities and lurking places in which they accumulate. It is also necessary that the current be well directed, and so conducted as to sweep the entire working face.

QUES. 318.—What effect has undiluted or pure carbureted hydrogen gas on life and on fires in mines? *F.—Pa. (B)*

ANS.—It is not a supporter of life or combustion; hence, its effect on life is to produce suffocation; a mine fire will be extinguished by it owing to a lack of oxygen.

QUES. 319.—What are the different noxious gases found in mines? *F.—Ind.*

ANS.—Any of the gases described in Ques. 312 may be noxious if present in sufficient quantity, but the term noxious gases usually means marsh gas, carbon monoxide, carbon dioxide, hydrogen sulphide, and nitrogen.

QUES. 320.—Describe the dangers attending the presence of the gases met with in coal mines. *F.—Pa. (A)*

ANS.—The danger attending the presence of marsh gas arises from the tendency of the gas to diffuse into the air and form an explosive mixture of firedamp. Carbon dioxide, or blackdamp, often called chokedamp, is dangerous when it accumulates in large quantities in the lower portions of the mine, and in abandoned working places where the ventilation is slack; this gas kills by suffocation, after first producing unconsciousness. Carbon monoxide, or whitedamp, is poisonous and perhaps the most dangerous of the mine gases, because its presence is not easily detected; lights burn in it more brightly than in pure air; the victim is overcome and rendered unconscious before being aware of the impending danger.

Hydrogen sulphide is dangerous, owing to its explosive character, when mixed with seven times its volume of air; it is also a poisonous gas, and will not support life or combustion. Nitrogen, oxygen, and hydrogen seldom or never occur alone in such quantities as to be dangerous.

QUES. 321.—How many cubic feet of carbon dioxide in a volume of 50,000 cubic feet of air, will make it injurious to health or fatal to human life? *F.—Pa. (B)*

ANS.—It was thought at one time that carbon dioxide had a poisonous effect on the human system, and that when present to the extent of ½ per cent, the results would be injurious, if not fatal, to human life, but later

experiments have wholly disproved this theory and have shown that carbon dioxide is not poisonous, and that an atmosphere containing 5 per cent. of this gas may be breathed for a considerable length of time without any more injurious effect than severe headache or nausea. The air expired from the lungs of a healthy person contains from 3 to 6 per cent. of carbon dioxide, and much of this air is often breathed over and over again by persons confined in a close room. It may, therefore, be assumed that 50,000 cubic feet of air may contain from 2,500 to 3,000 cubic feet of carbon dioxide without the mixture proving fatal to human life, unless breathed for a long period of time.

QUES. 322.—What produces whitedamp and blackdamp in mines? *F_1—Ala.*

ANS.—See answer to Ques. 312.

DETECTION OF MINE GASES

QUES. 323.—State how the several mine gases may be detected. In what proportion in the air are they fatal to life? In what proportion do they extinguish light? *F.—B. C., Canada*

ANS.—Marsh gas, CH_4, is detected by observing the height of flame cap formed in the Davy lamp when this gas is present in the air. When using the smallest possible flame (⅛ in.), the first cap generally discernible by the experienced eye under favorable conditions is a cap ½ in. high, formed in the lamp when the proportion of gas to air is 1 : 40; when the proportion of gas to air is 1 : 30, a cap is formed nearly ¾ in. high; a proportion of 1 : 25, gives a cap 1½ in. high; a proportion of 1 : 20, gives a cap 3½ in. high; a proportion of 1 : 16, produces a voluminous spindle-shaped flame spreading out in the upper portion of the gauze; beyond this point the entire gauze fills with flame. In the presence of gas where diffusion is rapidly taking place, slight explosions occur within the lamp just previous to flaming. Where a normal flame is used in testing, the height of the flame increases with the percentage of gas present, but no cap is visible. When the mixture contains between 5 and 6 per cent. of gas, there is a tall spire of flame that assumes a graceful curve, and rotates slowly about the central axis of the lamp. Marsh gas is not poisonous to the human system, and air containing a large percentage of this gas may be breathed for some time without producing other effect than a slight giddiness, which passes off on returning to fresh air. Pure marsh gas will extinguish the flame of a lamp; but the lamp will continue to burn in a mixture of marsh gas diluted with air.

Carbon monoxide, CO, often escapes detection in the air of the mine because the lamps burn more brightly in this gas than in pure air. The method of detecting this gas in mine workings is by the brightness of the flame, which reaches upwards in a slim, quivering, taper blaze. Air

containing .5 per cent. of carbon monoxide, when breathed for some length of time, will produce death. This gas, being a supporter of combustion, does not extinguish the flame of a lamp.

Carbon dioxide, CO_2, is detected by the dimness of the lamps, and their final extinguishment in an atmosphere containing much of this gas. Like marsh gas, it is not poisonous, but a much smaller percentage of this gas (10 per cent.), when present in the air and breathed for a considerable period of time, will produce fatal results; while 14 per cent. of carbon dioxide in the air is required to extinguish the flame of a lamp.

Hydrogen sulphide, H_2S, is easily detected by its smell, which resembles that of rotten eggs. This gas, like carbon monoxide, is a poisonous gas. It is stated by some authorities that 1 per cent. of the gas is fatal to life, while other authorities state that air containing as much as 3 per cent. of the gas has not produced fatal results. It is probable that the truth lies between these statements, and that 1 per cent. of the gas may be considered dangerous but not necessarily fatal. Like marsh gas, it is not a supporter of combustion, and lamps will not burn in an atmosphere of pure sulphureted hydrogen; but a considerable percentage of the gas is necessary in the atmosphere for the extinction of the flame of a lamp.

QUES. 324.—How are mine gases detected? *F_1.—Ala.*

ANS.—The common mine gases, with one exception (H_2S), are detected by the effect they produce on the flame of an ordinary lamp; in the detection of marsh gas, it is necessary to employ a safety lamp. Pure marsh gas, will not support combustion, since it contains no oxygen. The flame of the lamp would be at once extinguished in undiluted marsh gas. This gas, however, diffuses so rapidly into the air that such a condition is rarely, if ever, met with in mines. Marsh gas mixed with air in any proportion is readily detected by the small flame cap that forms on the flame of a safety lamp placed in this gas. The height of the flame cap serves to determine the amount of gas present in the mixture. When the proportions of gas and air are such that the mixture approaches the explosive point, the flame of the lamp becomes voluminous or spindle-shaped, and when testing with the normal flame, rotates in a weird manner about the central axis of the lamp. As the proportion of gas increases, the lamp fills with flame ("flames"), and small explosions occur within the gauze.

Carbon monoxide causes a lamp to burn more brightly, and the flame reaches upwards in a slim, quivering, taper blaze. The effect of carbon dioxide is to depress the flame of a lamp when a small percentage of the gas is present, the flame growing dim and being finally extinguished as the percentage of gas increases.

Hydrogen sulphide is detected by its smell, which resembles that of rotten eggs.

QUES. 325.—State the conditions under which the presence of the various mine gases may be expected. How may each be detected? *F.—Pa. (A)*

Ans.—The conditions that give rise to the presence of marsh gas are always found in the working of a gaseous seam of coal; in the exposure of a large amount of fresh coal at the working face, or a heavy fall of roof, which may liberate a large amount of gas contained in the roof strata; also in the presence of feeders, or pockets of gas in the coal seam itself or the contiguous strata.

The presence of carbon dioxide may be expected in dip workings or low portions of a large mine where there is a considerable extent of abandoned workings. This gas being heavier than air will always accumulate in the lower workings and passageways of mines where the ventilation is at all sluggish.

The presence of carbon monoxide may be expected in connection with abandoned workings, or the workings of mines where the ventilation is insufficient. The formation of this gas is due largely to the slow combustion of slack and fine coal in the waste places of the mine where there is a limited supply of air.

The presence of hydrogen sulphide may be expected in the working of coal seams containing a considerable amount of iron pyrites. The decomposition of the pyrites results in the formation of this gas. The gas is liable to occur frequently in the underlying strata and clays of coal seams containing pyrites; also as the result of gob fires.

Marsh gas is detected by observing the effects of the gas upon the flame of a safety lamp. Usually the flame of the lamp is first lowered to a small, uniform size. The lamp is then cautiously lifted toward the roof to where an accumulation of gas is suspected and the flame carefully watched for the first appearance of a flame cap.

The presence of carbon dioxide is indicated by the dimness of the lamps, and the total extinguishing of the flame when a sufficient amount of this gas is present.

In carbon monoxide the lamp continues to burn brightly and the flame of the lamp is lengthened and reaches upwards in a slim, tapering blaze, often surmounted by a bluish tip, which is, however, difficult to observe on account of the luminous body of the flame.

Hydrogen sulphide is detected by its strong smell, which resembles that of rotten eggs, from which it has received the name stinkdamp.

OCCURRENCE OF MINE GASES

Ques. 326.—Where are these gases found, and how are they produced? *M.—B. C., Canada*

Ans.—The lighter mine gases, as carbureted hydrogen and carbon monoxide, accumulate near the roof and the upper portions of mine workings, while the heavier gases, as hydrogen sulphide and carbon dioxide, accumulate near the floor and in the lower workings of the mine.

Marsh gas is produced by the metamorphism of carbonaceous matter away from air and in the presence of water, and is one of the products of the formation of every coal seam. The fact that a coal seam is gaseous or otherwise, is due to the fact that this gas has been retained or has escaped, as the case may be, according to the character of the overlying strata. If the cover of the seam is impervious to gas, the gas is retained in the coal, while pervious strata and fissures and faults allow the gas to escape to the surface and the seam becomes a non-gaseous seam.

Carbon dioxide is produced by the complete combustion of carbonaceous matter in a plentiful supply of air. The combustion may be a slow combustion as occurs in the decomposition of coal in the gob, and the decay of mine timber, etc.; or the more rapid combustion of mine fires, burning of lamps, etc. This gas is also produced by the breathing of men and animals.

Carbon monoxide is the result of the incomplete combustion of carbonaceous matter in a limited supply of air; this gas is produced by slow combustion in the gob where the supply of air is limited, and is also the result of mine explosions, blasting, etc., the supply of air being limited in these cases.

Hydrogen sulphide is apparently the result of the decomposition of iron pyrites; this often takes place in the floor of the seam in moist places in the mine.

QUES. 327.—In what part of a mine may gas be expected to be given off more freely than in other parts, and why?

B.—Pa. (B)

ANS.—Marsh gas is given off more freely at the working face, owing to the constant exposure of fresh faces of coal as the work advances. When this gas is contained in the roof, larger quantities are set free in pillar workings and on falls, owing to the disturbance of the roof setting the gas free. A squeeze or crush in a gaseous seam is almost invariably accompanied by a large outflow of gas into the workings Carbon dioxide is given off in larger quantities from abandoned workings, especially where water has accumulated. Gob fires are accompanied by a production of large quantities of carbon dioxide and carbon monoxide gases. Mine gases do not necessarily accumulate where they are given off; the lighter gases rise into the higher portions, or upper workings of the mine, where they accumulate unless the circulation is sufficient to carry them away; the heavier gases gravitate to the lower workings of the mine, where they accumulate until removed by the air-current.

QUES. 328.—Why is it that firedamp may be found and ignited near the roof of a mine when there is none near the bottom, and why does blackdamp seek the lower level? *F_1.—Ala.*

ANS.—Firedamp is an explosive mixture of marsh gas and air. Its density being less than that of air, the gas rises to the roof where it

accumulates, and is often ignited by a naked lamp or the flame of a blown-out shot, or otherwise. Blackdamp, or carbon dioxide, CO_2, has a density greater than that of air, and the tendency of this gas, therefore, is to sink to the floor of the mine, where it accumulates.

QUES. 329.—Why is it that marsh gas, CH_4, is generally found lodged near the roof, and carbon dioxide near the floor?
B.—Pa. (B)

ANS.—The specific gravity of marsh gas is .559. This gas being lighter than air accumulates at the roof and in the higher workings of the mine. The specific gravity of carbon dioxide is 1.529. The gas being heavier than air accumulates near the floor and in the lower mine workings. It is the law of gravity that causes the heavier gas to fall and the lighter gas to rise in the mine atmosphere.

DIFFUSION OF GASES

QUES. 330.—Explain the law of the diffusion of gases, and its effect on their behavior in mines. Give rule and example showing how to find the comparative velocity of the diffusion of different gases.
I.—Pa. (A)

ANS.—The velocity with which gases diffuse into each other varies inversely as the square roots of their densities. For example, the density of hydrogen being 1 and that of oxygen 16, the velocities of the diffusion of these two gases into each other will be inversely as the square roots of 1 and 16; i.e., the velocity of the diffusion of hydrogen is to that of oxygen as $\sqrt{16} : \sqrt{1}$, or as 4 : 1. In other words, the velocity with which oxygen will diffuse into an atmosphere of hydrogen is four times the velocity with which hydrogen will diffuse into oxygen. The specific gravity of marsh gas being .559, referred to air as 1, the relative rates of diffusion of marsh gas and air are as $\sqrt{1} : \sqrt{.559}$, or as 1 : .748; that is to say, 1,000 volumes of marsh gas will diffuse into air while 748 volumes of air diffuse into the gas.

QUES. 331.—How are gases caused to expand out of the strata, and at times to overflow the workings in a mine?
F_1.—Ala.

ANS.—By being liberated by a shot in blasting or by any accident suspending the ventilating power when the blowing system is in use, or by a short-circuiting of the air, caused by an open door or broken brattice, and lowering the water gauge or pressure. Under such conditions, gases expand and flow out of crevices, gobs, and other places containing standing gas, into the workings. This lowering of the water gauge is a feature that must be carefully guarded against in gassy mines using a blower fan. With a suction fan, the opposite effect would result from the stopping of the fan. When the barometer shows a low or lowering pressure, great care

should be taken, as the gases at such times expand and pass out of the crevices, etc. into the mine workings, and an efficient current of air is then required to dilute and carry them off.

QUES. 332.—Explain how the condition of the weather and direction of the wind may affect the production of gases in coal mines. *I.—Ia.*

ANS.—Whatever conditions operate at the surface to alter the air pressure in the airways of a mine, affect at once the amount of gas issuing from the strata and from old or abandoned workings. A fall of barometric pressure is felt very soon in the mine workings, and the gases contained in these places expand in proportion to the fall of pressure, and flow out on the airways, where they mingle with the air-current of the mine. In gaseous mines, there is always an increase in the gas issuing from the coal or from feeders in the mine, whenever there is a fall of barometric pressure. It has generally been observed that the fall of barometric pressure precedes the effect in the mine, by from 2 to 3 hours., and thus gives a sufficient warning to provide against the increase of gas that is sure to follow. A strong surface wind may possibly also produce a change in the gaseous condition of the mine when it acts to oppose the current discharging from the upcast.

BLACKDAMP

QUES. 333.—What is the composition of blackdamp, and what is it called other than blackdamp? *F_1.—Ala.*

ANS.—A molecule of blackdamp is composed of one atom of carbon and two atoms of oxygen and is designated CO_2; this gas is also called carbon dioxide, carbonic-acid gas, and chokedamp.

QUES. 334.—How do we distinguish between firedamp and blackdamp, and what are the characteristics of each? *E.—Ill.*

ANS.—The distinguishing characteristics of these two gases are as follows: Firedamp is a mixture of marsh gas, CH_4, and air in explosive proportions, and is combustible. It is lighter than air, the specific gravity of pure firedamp at its most explosive point being .9586. Carbon dioxide, or blackdamp, CO_2, is an incombustible gas, and is heavier than air, having a specific gravity of 1.529. Firedamp may be breathed for a considerable length of time with impunity, producing only a slight dizziness, which passes off on return to fresh air. Blackdamp suffocates by excluding the oxygen of the air from the lungs; smaller quantities of this gas produce headache and nausea; larger quantities produce unconsciousness, and finally death by suffocation. A body of firedamp may be ignited by the flame of a naked lamp; when a safety lamp is used, the less explosive mixtures of firedamp are indicated by the enlargement and motion of the flame in the lamp. The lamp becomes speedily filled with flame as the proportion

of marsh gas in the air is increased, and must be promptly but cautiously removed from the gas. Blackdamp when present in small quantities, in the air, dims the flame of the lamp, which is extinguished entirely when the gas is present in larger quantities. The presence of one-seventh of its volume of blackdamp in a body of firedamp at its most explosive point, reduces the liability of the latter to explode. Owing to its lower specific gravity (.9586) firedamp accumulates near the roof and in the higher portions of the mine workings, while blackdamp, having a greater specific gravity (1.529) accumulates at the floor and in the lower portions of the mine workings.

QUES. 335.—Where does the blackdamp found in coal mines originate? *E.—Ill.*

ANS.—The sources of blackdamp in mine workings are quite numerous, it being produced by the burning of lamps, breathing of men and animals, explosion of powder, and to a greater or less extent by all forms of combustion, in a plentiful supply of air. Blackdamp is also produced in a considerable quantity in the mine by the evaporation of the mine water holding it in solution.

FIREDAMP

QUES. 336.—What is firedamp? *B.—Pa. (B)*

ANS.—The term firedamp, in America, is usually understood to mean any explosive mixture of marsh gas and air. In England, however, the term is often applied to any mixture of gas and air, whether explosive or otherwise. Again, the term is sometimes applied to pure marsh gas by those who are not well informed. The meaning first mentioned, however, is the generally accepted meaning of the term.

QUES. 337.—What constitutes firedamp, and what gaseous mixtures does it include? *B.—Pa. (B)*

ANS.—The term firedamp generally means any mixture of mine gases and air in explosive proportions, although the term is applied differently in different localities. The gases usually present in firedamp mixtures are marsh gas and smaller proportions of the heavier hydrocarbons, such as olefiant gas, C_2H_4, ethane, C_2H_6, etc. There is often present a variable quantity of carbon dioxide, CO_2, and at times small quantities of hydrogen, H, and carbon monoxide, CO.

QUES. 338.—What gases enter into the composition of firedamp, and in what proportions? *B.—Ind.*

ANS.—Besides marsh gas and air, which form the chief elements in firedamp, there are also present, frequently, varying proportions of olefiant gas, C_2H_4, and ethane gas, C_2H_6. The proportions of marsh gas and air in firedamp vary from 1 : 13 to 1 : 5½ volumes.

QUES. 339.—What is the difference between light carbureted hydrogen and firedamp? *M.—B. C., Canada*

ANS.—Light carbureted hydrogen or marsh gas, CH_4, is a chemical compound of carbon and hydrogen, while firedamp is a mechanical mixture of marsh gas and air. The term firedamp, in America, applies to any explosive mixture of marsh gas and air; but in England, the term is broadened to refer to a mixture of marsh gas and air in any proportion, whether explosive or otherwise. Light carbureted hydrogen, though combustible, does not support combustion and is not explosive; it causes death by suffocation. Firedamp, on the other hand, supports combustion, is explosive, and may be breathed with impunity for a considerable length of time, the only effect produced being a slight giddiness, which passes off on return to fresh air.

QUES. 340.—From where does the firedamp come that is found in mines? *B.—Ind.*

ANS.—Marsh gas, by its mixture with the air, forms the firedamp of mines. Marsh gas comes either from the coal seam itself or, as is often the case, from the strata forming the roof or floor. In the seam, the gas is held in the pores of the coal where it has been occluded during the formation of the coal. When found in the strata beneath or above the coal seam, it has either formed in these strata when they were deposited, or it has escaped from the seam of coal and penetrated the crevices or pores of such strata under its own pressure. The gas exists in the strata as pure marsh gas or as a mixture of pure marsh gas with other hydrocarbons; but when it issues into the mine workings, it diffuses into the air and forms an explosive mixture called firedamp.

QUES. 341.—Where does firedamp come from and where may you expect to find it? *E.—Ill.*

ANS.—Firedamp is a mechanical mixture of gases produced in all the working places of a coal mine where air is present and light carbureted hydrogen escapes from the pores of the coal or the fissures in the floor or roof. It may also be looked for in the return air-currents coming from the places where it is formed, and, as it is lighter than air, it will collect in the higher portions of the mine workings, or at the top of a chamber if there is not enough to fill the whole chamber.

QUES. 342.—Where is firedamp chiefly found in a mine? *B.—Pa. (B)*

ANS.—This will depend on the local conditions. Owing to its lighter specific gravity, firedamp will accumulate in the higher portions of the mine workings; also in places where the ventilation is least efficient. The firedamp produced in one part of the mine may be diluted and carried away by the air-current before it can reach the higher workings, in which case the gas will be found most abundantly where it issues from the strata, and there will be no accumulated bodies of gas. New workings, or a freshly exposed face of coal exude much more gas than old workings. Where gas

occurs in the roof, its presence is more manifest in the gobs and waste places, and during the robbing of the pillars, owing to the frequent roof falls, which set free large quantities of the gas.

QUES. 343.—In what parts of a mine are firedamp and pure gas most likely to be found? *B.—Ind.*

ANS.—Pure marsh gas is most likely to be found at the immediate point where it issues from the coal or contiguous strata. If we consider a feeder coming from the roof strata of a coal seam, in the face of a chamber driven to the rise, the gas may accumulate in large quantities at the head of such a pitch in its natural state or unmixed with air, because this gas is lighter than air and its diffusion into the air is not rapid enough to form firedamp at the face. But if we consider a feeder in the floor of a coal seam, the gas issuing from such feeder tends to rise toward the roof, and in rising diffuses rapidly into the air, forming firedamp. We would be more likely to find a firedamp mixture in the higher places of a gaseous mine, where it has accumulated, having risen to this point from other portions of the workings.

QUES. 344.—What complications arise in the development and working of mines where firedamp exists? *F_1.—Ala.*

ANS.—In the working of gaseous seams, the escape of occluded gases from the pores of the coal takes place continuously all along the working face, where it is stronger and more plentiful than in any other portion of the mine, because the working face exposes fresh coal as it advances. These gases escape often under considerable pressure, and at times splinter and break the coal. At other times, the occluded gas escapes from a seam or crevice in the coal or roof of the mine and is then called a gas feeder. Such a feeder at times gives forth large volumes of gas, which diffuses at once into the atmosphere of the mine and forms firedamp. At other times, outbursts of gas occur, caused by the high pressure of the gases accumulated in a small pocket or crevice in the seam or the roof, and as the workings advance this pressure is exerted over a large area, causing a big fall of coal or roof. In any case, a large volume of gas is set free which renders the atmosphere of the mine at once highly explosive. It is always necessary in gaseous mines to maintain a sufficient volume of air in circulation to dilute the gases issuing from the seam or its contiguous strata.

QUES. 345.—Is firedamp compressible? What effect has a decreased pressure of the atmosphere on this gaseous mixture? *M.—B. C., Canada*

ANS.—Firedamp, like all other gases, is compressible. A decrease of atmospheric pressure results in an expansion of the volume of firedamp contained in the mine workings, and a large quantity of gas may be thus thrown into the air-current. There is also, generally, a freer transpiration of the occluded gases of the coal seams during a fall of atmospheric pressure.

AFTERDAMP

QUES. 346.—What is afterdamp, and what would be the composition of the afterdamp resulting from an explosion of firedamp containing a large quantity of air; and what would it likely be if the firedamp contained but a small quantity of air? *F_1.—Ala.*

ANS.—Afterdamp is the gaseous mixture remaining in mine workings after an explosion of firedamp has occurred therein. In the explosion of firedamp containing a large quantity of air, the afterdamp produced consists chiefly of carbon dioxide, water vapor, H_2O, and nitrogen, N, together with varying quantities of hydrocarbons. In the explosion of a body of firedamp in a limited supply of air, the afterdamp produced will contain, besides the gases mentioned, a varying amount of carbon monoxide, CO, and some unburned marsh gas, CH_4, and hydrogen, H.

QUES. 347.—What would probably be the composition of the explosive mixture if the firedamp showed the presence of whitedamp instead of blackdamp, and why? *F_1.—Ala.*

ANS.—The proportion 1 : 9.5, which indicates 1 volume of gas to 9.5 volumes of air, represents the firedamp mixture at about its most explosive point, or when the combustion of the marsh gas is complete, there being sufficient air present to completely burn the carbon and the hydrogen in the marsh gas. Now, when there is less air than this amount in the firedamp mixture the combustion will be incomplete and carbon monoxide or whitedamp, CO, will be produced instead of blackdamp, since this gas is always a product of incomplete combustion when the supply of air is limited.

QUES. 348.—Under what conditions may afterdamp become explosive? *I.—Ill.*

ANS.—When the afterdamp contains a considerable amount of carbon monoxide, CO, an explosive mixture is formed on contact with air. It sometimes occurs, also, that a considerable amount of unburned marsh gas is still present in the afterdamp, which only requires the addition of fresh air to render the mixture again explosive.

EXPLOSIBILITY OF FIREDAMP

QUES. 349.—What proportions of atmospheric air and light carbureted hydrogen are necessary to form an explosive mixture? *F.—Pa. (A)*

ANS.—A mixture of carbureted hydrogen or marsh gas and air becomes explosive when it contains 1 volume of marsh gas to 13 volumes of air; the mixture is then called firedamp.

Firedamp attains its maximum explosive force when it contains 1 volume of gas to 9.66 volumes of air.

As the quantity of marsh gas is further increased beyond this point, the explosive violence of the firedamp decreases, and reaches a minimum when the mixture contains 1 volume of gas to 5 volumes of air.

QUES. 350.—What is the proportion of marsh gas and air in a firedamp mixture that will develop the maximum explosive force? What are the limiting proportions that determine an explosive mixture of these gases? *F_1.—Ala.*

ANS.—A mixture of pure marsh gas and air develops its greatest explosive force when 1 volume of marsh gas is mixed with about 9.5 volumes of air.

The mixture first becomes explosive when the proportion of gas and air is 1 : 13; from this point, the explosive force increases as the amount of gas is increased, and reaches a maximum when the proportion of gas and air is 1 : 9.66; the explosive force then decreases as the amount of gas is increased, until the proportion of gas and air is 1 : 5; beyond this point the mixture is no longer explosive. The presence of other explosive gases or coal dust suspended in the air widens the explosive range of marsh gas, while the presence of carbon dioxide reduces the range of explosion.

QUES. 351.—Name the different gases destructive to life or injurious to health, encountered in coal mines. Give their combining proportions with air as they relate to mines. *I.—Pa. (B)*

ANS.—The common mine gases are as follows: light carbureted hydrogen, or marsh gas, CH_4; olefiant gas, C_2H_4; carbon monoxide, CO, often called white damp; carbon dioxide, CO_2, often called blackdamp or chokedamp; hydrogen sulphide, H_2S, sometimes called stinkdamp. The gaseous mixtures that commonly occur in mines are: firedamp, a mixture of marsh gas and air in explosive proportions; and afterdamp, a variable mixture of numerous gases in different proportions. The gases forming afterdamp are principally, carbon dioxide, carbon monoxide, and nitrogen, together with some heavy hydrocarbons. The explosive proportions of marsh gas and air forming firedamp are as follows:

Lower explosive limit...... volume of gas to air,	1 : 5.50
Maximum explosive force... volume of gas to air,	1 : 9.66
Higher explosive limit...... volume of gas to air,	1 : 13.00

These proportions refer to pure firedamp. The presence of coal dust or other gases alters the explosive range of the firedamp mixture. The combining proportions with oxygen per maximum explosive mixture are:

Carbon monoxide, ½ volume of oxygen;
Hydrogen sulphide, 1½ volumes of oxygen;
Marsh gas, 2 volumes of oxygen;

or the combining proportions with air to produce maximum explosive mixtures are:

Carbon monoxide..................	2.415 volumes of air
Hydrogen sulphide................	7.245 volumes of air
Marsh gas........................	9.660 volumes of air

QUES. 352.—How many cubic feet of air would be necessary to dilute and render harmless 500 cubic feet of marsh gas, CH_4?
B.—Pa. (B)

ANS.—A mixture of marsh gas, CH_4, and air in the proportion of 1 volume of gas to 13 volumes of air is at its explosive limit; and any larger proportion of air, under ordinary conditions, renders the mixture inexplosive. The quantity of air that would render 500 cu. ft. of marsh gas inexplosive would then be $500 \times 13 = 6{,}500$ cu. ft. Although this mixture is inexplosive under ordinary conditions, it would hardly be considered safe or harmless in a mine. Mine air under ordinary conditions should not contain more than, say, 2 per cent. of marsh gas. Assuming the 500 cu. ft. of marsh gas to be 2 per cent. of the entire circulation and the remaining 98 per cent. pure air, the quantity of air required to produce this result would be

$$\frac{98}{2} \times 500 = 24{,}500 \text{ cu. ft.}$$

QUES. 353.—If it were known that 1,000 cubic feet of carbureted hydrogen gas per minute was being given off in a certain district, what amount of air would you require to circulate in that district in order to dilute and render this gas harmless, and also to provide sufficient air for 100 men and 10 horses? *M.—B. C., Canada*

ANS.—Since the explosive limit of marsh gas or carbureted hydrogen, CH_4, is reached when the proportion of air and gas is 1 : 13, the quantity of air required to dilute 1,000 cu. ft. of marsh gas to this explosive limit is

$$1{,}000 \times 13 = 13{,}000 \text{ cu. ft. per min.}$$

and any further addition of air would render this quantity of gas inexplosive. However, for safe conditions in the mine workings, the quantity of gas present should not exceed about 2 per cent. of the mixture; that is to say, 1,000 cu. ft. of gas should be 2 per cent. of the entire circulation, the remaining 98 per cent. being pure air. The quantity of air to be supplied to the mine to produce these conditions would therefore be

$$\frac{98}{2} \times 1{,}000 = 49{,}000 \text{ cu. ft. per min.}$$

This quantity of air is largely in excess of that required by law for the given number of men and horses.

QUES. 354.—If 20,000 cubic feet of air and gas at its most explosive point are passing through the mine, what is the quantity of gas given off, and what quantity of air should be added to render it non-explosive? *B.—Pa. (B)*

ANS.—A firedamp mixture at its most explosive point contains 9.38 per cent. of gas, and 20,000 cu. ft. will contain

$$20{,}000 \times \frac{9.38}{100} = 1{,}876 \text{ cu. ft. of gas,}$$

and

$$20{,}000 - 1{,}876 = 18{,}124 \text{ cu. ft. of air}$$

Firedamp is at its higher explosive limit when the proportion of gas and air is 1 : 13; that is to say, when there is thirteen times as much air as gas the mixture will be feebly explosive. In this case, there being 1,876 cu. ft. of gas, the quantity of air that will dilute this gas to the explosive limit is

$$1{,}876 \times 13 = 24{,}388 \text{ cu. ft. of air}$$

The quantity of air to be added, therefore, in this case to reach the explosive limit is

$$24{,}388 - 18{,}124 = 6{,}264 \text{ cu. ft.}$$

When more air than this is added, the mixture ceases to be explosive.

Ques. 355.—How many cubic feet of air should be mixed with 1 cubic foot of firedamp to render it harmless? *F.—Ala.*

Ans.—Assuming that the firedamp is at its most explosive point, the proportion of marsh gas to air is then about 1 : 9.5; or there is 1 cu. ft. of marsh gas contained in every $1+9.5 = 10.5$ cu. ft. of firedamp; or there is about $1 \div 10.5 = .0952$ cu. ft. of marsh gas in every cubic foot of firedamp. Firedamp ceases to be explosive when the proportion of marsh gas to air is greater than 1 : 13. Then, since there is .0952 cu. ft. of gas and $1-.0952 = .9048$ cu. ft. of air in 1 cu. ft. of the firedamp, to dilute this mixture to the explosive limit will require

$$.0952 \times 13 = 1.2376 \text{ cu. ft. of air,}$$

or

$$1.2376 - .9048 = .3328 \text{ cu. ft.}$$

of air must be added to reach the explosive limit, and any further addition of air will render the mixture inexplosive, under ordinary conditions.

Ques. 356.—How many cubic feet of marsh gas will be required to be generated in a mine per minute to render dangerous a current of 30,000 cubic feet of air per minute? *E.—Ill.*

Ans.—Although the explosive limit of pure firedamp is reached when the proportion of marsh gas to air is 1 : 13, a dangerous condition may be considered as existing when the current contains 3 per cent. of gas and $100-3 = 97$ per cent. of air. Since there are, in this case, 30,000 cu. ft. of air per min. in circulation, the quantity of gas required to produce dangerous conditions in this mine is

$$\frac{30{,}000}{.97} - 30{,}000 = 927+ \text{ cu. ft. per min.}$$

The experiments of Galloway, Abel, and others, have clearly shown that under favorable conditions mine air containing but 1 per cent. of marsh gas may be explosive.

Such conditions obtain when the firedamp mixture contains other gases than pure marsh gas, or when coal dust is held in suspension in the atmosphere of the mine. Explosive conditions are often induced by a concussion created by the explosion of a blast, or the sudden closing of a mine door, or other cause, when the percentage of gas present in the current is low.

Ques. 357.—What percentage of firedamp is the most dangerous? *F_1.—Ala.*

Ans.—This question probably refers to the percentage of marsh gas in the air-current that is the most dangerous. There is often greater possibility of an explosion of gas taking place when the percentage of gas is small, say from 1 to 3 per cent., depending on the conditions and the use of open lights, than when the presence of a larger percentage of gas demands the exclusive use of safety lamps in all parts of the mine. The percentage of marsh gas in firedamp when the mixture is at its most explosive point is 9.38 per cent. While the higher and lower explosive limits of pure marsh gas are marked by 7.14 per cent. and 15.38 per cent., respectively, of this gas in air, the presence of small amounts of other gases or of fine inflammable dust suspended in the air may cause an explosion when but 1 per cent. of marsh gas is present.

Ques. 358.—What proportion of firedamp in an air-current forms an explosive mixture of the least dangerous character? *M.—Ill.*

Ans.—Under ordinary conditions a firedamp mixture is least dangerous when the proportion of gas and air is 1 : 13 (higher explosive limit); because at this point the mixture is only feebly explosive and any further addition of air renders the mixture inexplosive.

Ques. 359.—Are there any possible conditions known to you, and which may occur in a mine in Illinois, that would make the combination given by you in answer to the preceding question as the least dangerous, one of a very highly dangerous character, no further addition of firedamp being made to the current? *M.—Ill.*

Ans.—The possible condition that would render a mixture of 1 part of marsh gas and 13 parts of air highly explosive without the addition of more gas is the presence of coal dust in the mixture. Coal dust widens the explosive range of firedamp.

Ques. 360.—What effect would carbon dioxide, CO_2, have on marsh gas, CH_4, when mixed together? *B.—Pa. (B)*

Ans.—Carbon dioxide when mixed with firedamp (CH_4 and air) at its most explosive point, in the proportion of 1 volume of carbonic-acid gas to 7 volumes of the firedamp, renders the latter inexplosive, and any addition of CO_2 to firedamp decreases its explosibility.

Ques. 361.—In dealing with light carbureted hydrogen, is any other danger to be guarded against besides that of explosion? *M.—Ill.*

Ans.—Light carbureted hydrogen, unless sufficiently diluted with air, will cause death by suffocation. In avoiding the danger arising from its explosive character as firedamp, other dangers that may exist incident to the presence of this gas are at the same time provided for.

CALCULATIONS

QUES. 362.—There is passing through a heading a mixture of air and marsh gas, at its most explosive point, amounting to 5,000 cubic feet per minute; what additional quantity of air must be added to this mixture to render it harmless? *B.—Pa.* (*B*)

ANS.—Firedamp, or a mixture of air and marsh gas, at its most explosive point consists of 1 volume of marsh gas to about 9.5 volumes of air; or, for every volume of gas, there is about $1+9.5 = 10.5$ volumes of firedamp mixture. Hence, the amount of gas in this mixture is approximately

$$\frac{1}{10.5} \times 5{,}000 = 476+ \text{ cu. ft.}$$

A firedamp mixture ceases to be explosive when the proportion of gas to air is greater than 1 : 13. The air required to render this amount of gas inexplosive will, therefore, be any amount greater than

$$476 \times 13 = 6{,}188 \text{ cu. ft.}$$

of air. The quantity of air to be added to the above mixture must therefore exceed

$$6{,}188-(5{,}000-476) = 1{,}664 \text{ cu. ft. of air per min.}$$

QUES. 363.—Suppose that in a fiery mine the quantity of air is 175,000 cubic feet per minute, measured in the return, and contains 4 per cent. (or 1 in 25) of firedamp when the barometer is 30. What quantity of firedamp is given off in the mine? What is the least decrease of the quantity of air that will render the return air explosive? What increase of gas will render the return air explosive? *I.—Pa.* (*B*)

ANS.—Assuming that the term firedamp here means marsh gas, the quantity of this gas given off in the mine is

$$175{,}000 \times .04 = 7{,}000 \text{ cu. ft. per min.}$$

Assuming that the explosive limit is reached when the proportion of gas to air is 1 : 13, the quantity of air, then, in circulation will be

$$7{,}000 \times 13 = 91{,}000 \text{ cu. ft.}$$

The original quantity of air passing in the intake of this mine is

$$175{,}000-7{,}000 = 168{,}000 \text{ cu. ft. per min.}$$

The decrease of air in the intake required to reach the explosive limit is then,

$$168{,}000-91{,}000 = 77{,}000 \text{ cu. ft.}$$

Hence, if the circulation in the intake is decreased from 168,000 to 91,000 cu. ft. per min., or, in other words, if there is a reduction of 77.000 cu. ft per min. in the air entering the mine, the return current will become explosive. The quantity of gas necessary to cause the intake current to reach the explosive limit is

$$168{,}000 \div 13 = 12{,}923+ \text{ cu. ft. per min.}$$

and the required increase in the flow of gas into the mine is therefore

$$12{,}923-7{,}000 = 5{,}923 \text{ cu. ft. per min.}$$

QUES. 364.—A bore hole from the surface is 6 inches in diameter and enters the rib fall in a mine; a mixture consisting of 50 per cent. of CH_4 and 50 per cent. of air is passing up this hole with a velocity of 130 feet per minute, what is the volume of the flow, in cubic feet per minute, and what would be its volume if sufficient air were added to bring the mixture up to the highest explosive point? *B.—Pa.* (*B*)

ANS.—The total volume of air and gas discharged from this bore hole per minute is

$$.7854 \times .5^2 \times 130 = 25.52 \text{ cu. ft.}$$

Since this volume contains 50 per cent. of marsh gas, CH_4, the volume of gas discharged per minute is

$$25.52 \times .50 = 12.76 \text{ cu. ft.}$$

A firedamp mixture at its most explosive point contains 9.38 per cent. of gas; hence, the volume of the gaseous mixture after adding sufficient air to bring it up to its most explosive point will be

$$12.76 \div .0938 = 136+ \text{ cu. ft. per min.}$$

QUES. 365.—Is there any condition under which the bore hole mentioned in the preceding question would become dangerous? If so, state the condition. *F.—Pa.* (*B*)

ANS.—In the exhaust system of ventilation, the hole would furnish an intake for a current of fresh air, and a large quantity of highly explosive gas would then be drawn from the falls into the main airways of the mine.

DETECTION OF MARSH GAS WITH A SAFETY LAMP

QUES. 366.—What percentage of marsh gas in the air makes itself apparent in the safety lamp? *E.—Ill.*

ANS.—In the use of the common Davy lamp for testing, the ordinary miner cannot detect much less than 3 per cent. of gas. With the Ashworth-Hepplewhite-Gray lamp, an experienced observer may detect 2.5 per cent. of gas; and with the Wolf naphtha lamp, it is claimed that 1 per cent. of gas may be detected and $\frac{3}{4}$ per cent. by an experienced person. Other special forms of lamps for testing, however, as the Pieler lamp, or the Clowes hydrogen lamp, or the Stokes lamp using an alcohol flame detect as low as $\frac{2}{10}$ per cent. of gas. The Beard-Mackie sight-indicator introduced into any safety lamp shows the presence of gas as low as $\frac{1}{2}$ per cent. by the incandescence of platinum wires supported above the flame.

QUES. 367.—A mixture of marsh gas and air, at its most explosive point, is passing along an airway 4 ft. × 5 ft. at an average velocity of 500 feet per minute; what quantity of fresh air must

be added to this current so that you will not be able to detect the gas on the safety lamp? *B.—B. C., Canada*

ANS.—The area of the airway is $4 \times 5 = 20$ sq. ft.; and the velocity of the current being 500 ft. per min., the quantity of air and gas in circulation is $20 \times 500 = 10{,}000$ cu. ft. per min. Assuming that 9.38 per cent. of this current is marsh gas (the mixture being at its most explosive point) the quantity of gas in circulation is

$$10{,}000 \times \frac{9.38}{100} = 938 \text{ cu. ft. per min.}$$

When the percentage of gas falls below about 2.5 per cent. the amount is too small to be detected on the flame of any ordinary safety lamp. (See answer to Ques. 366.) The quantity of the circulation when this volume of marsh gas is just observable on the lamp, is then, $938 \div .025 = 37{,}520$ cu. ft. per min. The volume of air, therefore, necessary to be added to the circulation, or the additional quantity of air required per minute, is

$$37{,}520 - 10{,}000 = 27{,}520 \text{ cu. ft. per min.}$$

QUES. 368.—A current of 3,000 cubic feet of air is at the explosive point, how much fresh air must be added to prevent a cap? *B.—Pa. (B)*

ANS.—Assuming the current to be at its most explosive point, or that it contains 9.38 per cent. of marsh gas, the quantity of gas in circulation in this current is $3{,}000 \times .0938 = 281.4$ cu. ft. In order that no cap may be formed in an ordinary safety lamp, the circulation must be increased so that this quantity of gas will be, say $2\frac{1}{2}$ per cent. of the total volume of the current, or $281.4 \div .025 = 11{,}256$ cu. ft.; this will require the addition of

$$11{,}256 - 3{,}000 = 8{,}256 \text{ cu. ft. of air}$$

ACCUMULATION OF GAS

QUES. 369.—Name the dangerous gases commonly found in mines, and the precaution you would take to insure the safety of your men while working near an accumulation of such gas. *F.—Pa. (A)*

ANS.—All of the common mine gases in mine workings are dangerous when allowed to accumulate in any considerable quantity. These gases are described in Ques. 312. The precautions necessary to be taken to secure the safety of men working near accumulated gases will depend on the nature of the gas. In case of an accumulation of marsh gas or firedamp, carbon monoxide, or hydrogen sulphide, extra precautions will be required on the part of the men to avoid the ignition of such gas. These precautions may require the use of safety lamps, if there is much gas present, or if there is the slightest possibility of the gas being ignited by the men. The

precaution should be taken in all accumulations of gas to approach the same from the intake side so as to avoid, as far as possible, coming in contact with the gas and the consequent danger of being overcome thereby.

QUES. 370.—In what mines would you expect to find the most dangerous accumulations of carbon dioxide and hydrogen sulphide gases, and why would they be found there? *I.—Pa. (B)*

ANS.—In mines overlaid by beds of limestone through which considerable quantities of water pass before entering the mine. As these waters percolate through the strata, they are subject to a continually increasing pressure head; carbon dioxide is soluble under ordinary pressures, in the proportion of 1 volume of the gas to an equal volume of water and its solubility increases as the pressure increases; it follows therefore that when this water enters the mine passages and the pressure head is reduced, every cubic foot of the water may liberate several times its volume of gas, the quantity being proportional to the pressure to which the water was subjected. Sulphureted hydrogen is mainly generated in the strata overlying or underlying a coal seam, being produced by the chemical action of sulphuric acid on iron pyrites; this gas accumulates in fissures and in the open space of faults, and when these are cut through, during the process of working coal, large volumes of the gas are set free.

QUES. 371.—In which part of the workings of a mine is the greatest pressure required for the removal of firedamp or marsh gas? *F.—Pa. (A)*

ANS.—A greater pressure will be required in the rise workings where this gas accumulates. It is often difficult to remove a body of marsh gas from the face of a steep pitch owing to the tendency of the gas to rise.

QUES. 372.—Is there more liability of having dangerous accumulations of explosive gases in high than in low seams? *B.—Pa. (B)*

ANS.—Dangerous accumulations of explosive gases are more liable to occur in high than in low seams for two reasons: (*a*) the velocity of the air current, in high seams, is liable to be too low to sweep out the gases, owing to the increased area of the air passages, at the face; (*b*) in high seams, there are liable to occur large cavities, in the roof and elsewhere, that will furnish places for the accumulation of gas.

QUES. 373. Which is the easier to clean out of a room, blackdamp or firedamp? Why is this? *M.—Ill.*

ANS.—The comparative ease of removing a body of blackdamp or a body of firedamp from a room depends largely on whether the room is driven to the dip or to the rise. Blackdamp being heavier than air will accumulate at the floor and in the dip workings, while firedamp being lighter than air will accumulate near the roof or in the rise workings. Hence,

if the room is driven to the dip, it will be easier to remove a body of fire-damp than a body of blackdamp; but if the room is driven to the rise, it will be easier to remove the blackdamp than the firedamp.

QUES. 374.—Which is the most difficult gas to contend with in mining? Explain fully. *B.—Pa.* (*B*)

ANS.—The difficulty encountered in contending with a large body of any particular gas depends chiefly on the conditions in the workings with respect to the inclination or dip of the seam. The lighter gases, as marsh gas and carbon monoxide, are more easily handled in the ventilation of dip workings, while the heavier gases, as carbon dioxide and hydrogen sulphide, are more readily handled in rise workings. This is due to the specific gravities of these gases assisting their removal in each case. The lighter gases having a lower specific gravity tend to rise to the higher portions of the mine, while the heavier gases owing to their greater specific gravity tend to fall to the lower portions of the mine where they accumulate until removed by the current. Therefore, if the lighter gases are generated in the upper workings of a mine, the ventilation will be accomplished much more readily than if the reverse of this is true.

The manner of occurrence of the gas will also increase or decrease the difficulty of contending with the same. Gas feeders occurring in the floor of the workings are often troublesome from their becoming ignited by the flame of a blast and drawing back under the gob or waste where it is difficult to extinguish them. If not extinguished, these gases become a menace to the safety of the mine, inasmuch as they are liable to cause a mine fire of considerable proportions in the gob. Such gas feeders should be followed up and extinguished if it is possible to do so. A means often employed for this purpose is the exploding of a small amount of dynamite in the workings in close proximity to the burning feeders. The concussion of the explosion will generally extinguish the burning gas. Gas feeders occurring in the roof of mine workings are often difficult and dangerous to contend with owing to their accumulating above the roof slate, and causing the same to settle away from the strata or producing heavy falls of roof and the sudden liberation of large quantities of gas.

QUES. 375.—If, when making an examination of a mine, you found a large body of explosive gas, state what precautions you would take to prevent an accident from same? *B.—Pa.* (*B*)

ANS.—If the gas is discovered previous to the entry of the men, they should not be permitted to enter the mine and no portion of the mine should be worked until the danger is removed. The fire-boss making the discovery should proceed at once to the entrance of the mine, or district where the gas is located, and post the proper danger signals at that point to prevent any person from entering the mine or district affected. Immediately after entering his report on the mine book, he should notify the mine foreman, and steps should be at once taken to remove the gas and to protect the mine in every way possible.

PROTECTION OF MEN FROM GAS

QUES. 376.—What precautions should be taken in entering an abandoned mine? *I.—Ia.*

ANS.—The precautions necessary to be taken in entering an abandoned mine relate particularly to the condition of the mine with respect to gases. In Iowa mines, the presence of blackdamp or carbon dioxide, or whitedamp or carbon monoxide forms the chief danger since there is little, if any, marsh gas in the Iowa coal seams. The danger is greater when there is little circulation of air in the old workings, and especially if there is a tendency to gob fires in the mine, since in such cases there will be a large amount of whitedamp given off. The presence of whitedamp is often not readily detected, when entering an abandoned working place, since the lamps continue to burn brightly in this gas. The effect of the gas on life is deadly, as it poisons the system, producing unconsciousness and death in a comparatively short time.

QUES. 377.—Under what conditions in a mine does the Anthracite Mine Law require the mine foreman to withdraw the men under his charge? *F.—Pa. (A)*

ANS.—General rule 8 of the Anthracite Mine Law of Pennsylvania reads as follows:

If at any time it is found by the person for the time being in charge of the mine or any part thereof, that by reason of noxious gases prevailing in such mine or in such part thereof, or of any cause whatever, the mine or the said part is dangerous, every precaution shall be used to insure the safety of the workmen. And every workman, except such persons as may be required to remove the danger, shall be withdrawn from the mine, or such part thereof as is so found dangerous, until the said mine or said part thereof is examined by a competent person and reported by him to be safe.

QUES. 378.—If a mine that you had charge of were to suddenly develop firedamp, what would you consider your duty according to the laws of Alabama? F_1.—*Ala.*

ANS.—Under the provisions of Section 8 of the Alabama Mine Law, it would be the duty of the mine boss to at once take steps to increase the ventilation of the mine to such an extent as would "dilute, carry off, and render harmless" the gases issuing from the working face. It would be necessary to at once withdraw all the men from the affected district. The ventilating current should then be gradually increased in the affected district by speeding the ventilator, or by throwing all the air of the mine into the district where the trouble exists, after withdrawing the men from the other districts of the mine.

QUES. 379.—Referring to the previous question, what instructions would you issue to your fire-boss? F_1.—*Ala.*

ANS.—The fire-boss should be instructed to proceed at once to the affected district where the gas was issuing, and withdraw all the men as rapidly as possible, and to see that all naked lights are at once extinguished, if such lights are in use in the district. He should do all in his power to increase the air and maintain an ample circulation in the district affected, and to see that this air is conducted as well as possible to the place where the gas is issuing. In doing this, he should proceed with the air-current, and not permit himself to incautiously enter any unventilated portions where a body of gas may have accumulated. His efforts should be directed to throwing the whole of the air-current forwards so as to sweep the face where the gas is issuing. He should, from time to time, make a test as far as practicable of the return of the current sweeping this portion of the working face.

REMOVAL OF GAS FROM MINE WORKINGS

QUES. 380.—How would you proceed to clear a shaft that is filled nearly to the top with carbon dioxide? *F.—Ia.*

ANS.—This gas, being heavier than air, is difficult to remove from the bottom of a shaft while sinking. In sinking a small shaft with no partition dividing the shaft, the gas has been sometimes removed by buckets in the same manner as water is hoisted, but this method is slow and not to be recommended. A steam jet or blower may be lowered into the shaft to clear out the gas, but a fire-basket cannot be used effectively, because the gas will quickly put out the fire. An air-tight partition should always be carried down the shaft and kept close to the bottom while sinking, so as to provide for a separate downcast and upcast column of air. When the natural ventilation of the shaft is not sufficient, or much gas is produced in sinking, the top of this airway may be covered and connection made with a small fan, producing a current of air sufficient for the ventilation of the shaft. When the shaft is filled with gas nearly to the top, a strong current of air will be required to start the circulation, owing to the great weight of this gas, which is $1\frac{1}{2}$ times as heavy as air; the circulation in this case may be started by pouring water down one side of the shaft.

QUES. 381.—In an old mine generating explosive gases what dangers arise that are not found in new mines generating such gases, and how would you overcome such dangers? *I.—Pa. (B)*

ANS.—The conditions in an old mine relative to mine gases are very different from those in a new mine. The old mine will usually contain a large area of abandoned workings, more or less filled with gas, which is sensitive to atmospheric changes, and which expands into the mine workings at every fall of the barometer. There is also greater danger of the accumulation of gas on the falls in old mines. In a new mine, the gas issuing from the working face in regular quantity is more easily provided for and controlled, since it is carried away as quickly as it issues, by the

current of air passing the face of the workings. To overcome the dangers in old mines, the abandoned workings should be efficiently ventilated by a plentiful supply of air so as to carry away the gas as it issues from the strata.

QUES. 382.—What is the best means of removing dangerous gases and keeping the atmosphere of the mine in a good, healthy condition? *F_2.—Ala.*

ANS.—An adequate supply of air should be maintained in circulation in the mine. The air-current should be so conducted as to sweep the entire working face. Where necessary, brattices or curtains should be erected to deflect the air-current against any bodies of gas accumulated in the cavities of the roof or sides from abandoned places in the mine. Abandoned workings should be kept free from standing gas by efficient and ample ventilation. The velocity of the current at all points of the mine should be such as to sweep out the gases that accumulate. All doors, stoppings, and air bridges should be made air-tight so as to reduce the loss of air from leakage.

QUES. 383.—How would you remove firedamp from a working place, or render it harmless? *B.—Ind.*

ANS.—The first step in the removal of any considerable body of gas from a working place is to notify the men working on that air split or in that district of the mine, and withdraw them from the mine. The air-current in that split or district is then gradually increased, and directed particularly into the chamber or working place where the gas is lodged and made to sweep the entire chamber. It may be necessary to erect special brattices to accomplish this thoroughly, as the air-current may need to be deflected upwards into a cavity of the roof, or conducted into some unused parts of the goaves. The air-current must be under complete control in this district. The undertaking is an operation that requires great caution and painstaking; safety lamps should be used, and only experienced men should be employed under the direction of the fire-boss. It may be deemed necessary to withdraw all the men from the mine before attempting to drive out the gas. This is a question for the judgment of the fire-boss.

QUES. 384.—If the open cavities in the abandoned part of a mine contained accumulations of explosive gas, what method would you adopt to render the gas harmless as far as practicable, and to keep the mine in a safe condition? *B.—Pa. (B)*

ANS.—As far as practicable, the abandoned portions of a mine should be ventilated by a separate current of air returning directly to the main return airway, so that the gases accumulating on the falls will not be carried into the mine workings. A sufficient quantity of air should be passed through the old workings to dilute and render harmless any gas accumulating in them.

QUES. 385.—State how you would commence to remove a large body of firedamp, and what precautions you would take. State what danger there would be in doing the work.
F.—B. C., Canada

ANS.—The work of removing a large body of firedamp is a dangerous task, and must be conducted with the utmost caution. Following are some of the main points to be considered: (1) The men working on the current and affected by the gas should be notified and withdrawn before any steps are taken toward removing the gas. (2) Only experienced and faithful men should be entrusted with the work of removing the gas. (3) Men should first be stationed at all points leading to the affected district and the doors should be arranged in such manner that the gas will pass out of the mine by the shortest possible route. (4) When all is in readiness, steps should be taken to increase the circulation bearing on the body of gas. As usual, much will depend on the conditions relative to the quantity of gas present, its location, and the arrangement of the passageways.

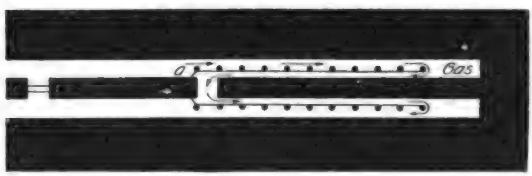


FIG. 1

(5) When necessary to erect a brattice extending up the heading to the point where the gas is located (Fig. 1), this should be done by setting a line of posts along one side of the heading about 18 in. or 2 ft. from the rib, and nailing brattice cloth or boards to these posts to form a partition or brattice that will carry the air forwards. In this work, the principal danger exists in the liability of igniting the gas. Safety lamps should be used and these should be kept at a safe distance back from the end of the brattice; the latter should be extended in sections as required so as to remove a small portion of the gas at a time. Great danger would be incurred by attempting to remove the gas too rapidly, or faster than the current could dilute it. The work should be conducted on the intake side and proceed slowly, and time should be given for the gas to pass off quietly. It will generally be safer to examine the air to ascertain the progress of the work, on the return side, especially when working on a pitch.

QUES. 386.—How would you proceed to remove a body of CH_4 from a series of breasts pitching 30°, the gas having accumulated during a stoppage of the fan? *F.—Pa. (A)*

ANS.—Select a few experienced competent men, and equip them with the best type of safety lamp. The foreman should take charge of the work, assisted by the fire-boss. Precautions should be taken to see that no one enters the portion of the mine containing the gas except those engaged in removing it. A split of air should be taken up the outside breast, by means of brattice cloth, or a board brattice, direct from the main intake

airway, and if the air split ordinarily furnished this part of the mine is not sufficient to move the body of gas another split should be directed into it and if possible the pressure increased. Extreme care must be taken that the return current from the affected portion of the mine does not come in contact with a light.

Proceed in the same manner in the next breast inside, and so on along the entire group, if necessary repairing the stoppings in the cross-headings so as to cause the air-current to sweep the faces of the breasts.

QUES. 387.—How would you proceed to remove a sudden accumulation of firedamp? *F_1.—Ala.*

ANS.—See answer to preceding question. Where furnace ventilation is in use, even where a dumb drift is provided, it will be necessary to remove the gas very cautiously and in small quantities, keeping the return air well below the explosive point. When the return current passes through the furnace, a door should be arranged to allow fresh air to enter the return at a point near the furnace, so as to dilute the gas below the explosive point before it reaches the furnace, and careful men should be stationed here for that purpose. This was done once in the rock slope of shaft No. 1, Pratt mines, very successfully. Here the return air passed up a shaft, at the bottom of which boilers were located, and the heat from the coal burned under the boilers created a sufficient air-column for the ventilation of the mine. Furnace ventilation, however, is always dangerous in a gaseous mine, even though the quantity of gas generated may be small.

QUES. 388.—Should you have a body of firedamp in a section of a mine and the ventilating current in that section is insufficient to remove the danger, how would you proceed to remove the gas, and what precaution would you use? *F.—Pa. (A)*

ANS.—Withdraw all the men from the mine. Use safety lamps and increase the ventilation in the affected district by throwing all the air into that district until the gas is removed. Caution should be used in bringing the air-current to bear on the body of gas; and especial caution is necessary in entering the chamber or working place where the body of gas is located, for the purpose of ascertaining the progress being made in its removal. The explosive condition of the firedamp is often more dangerous at the intake side of a large body of gas than on the return side where the diffusion is more complete. Under these conditions, therefore, the approach to the gas on the intake side must be made with great caution. It is often better to examine the air on the return side of the chamber or brattice.

QUES. 389.—If you were acting as fire-boss, and had an entry driven 200 feet ahead of the last cut-through, and you found in your examination that the entry contained explosive gas back 100 feet from the face, how would you proceed? *B.—Pa. (B)*

Ans.—The mine foreman in this instance has gone contrary to the Bituminous Mine Law, Art. 6, Sec. 3, with respect to driving an entry too far in advance of the air. The section reads as follows:

Sec. 3. It shall be the duty of the mine foreman to see that proper cut-throughs are made in all the room pillars at such distances apart as in the judgment of the mine inspector may be deemed requisite, not more than thirty-five nor less than sixteen yards each, for the purpose of ventilation and the ventilation shall be conducted through said cut-throughs into the rooms by means of check-doors made of canvas or other suitable material placed on the entries or in other suitable places and he shall not permit any room to be opened in advance of the ventilating current. Should the mine inspector discover any room, entry, airway or other working places being driven in advance of the air-current contrary to the requirements of this section he shall order the workmen working in such places to cease work at once until the law is complied with.

The first thing to be done under the circumstances would be to withdraw all the men working in these entries and on the return current. The fire-boss should then, with the assistance of experienced men, erect a temporary brattice starting from the outby rib of the last cut-through, by setting posts from this rib forwards toward the face of the entry in a line about 2 ft. from the rib, as shown in Fig. 1. Canvas or brattice cloth is then nailed to the posts, forming a brattice around which the air-current is forced to circulate. The men should work on the outby side of the brattice until they reach the point where the gas is located. The circulation may be gradually increased, if necessary, but the work should be carried forward with great caution, constant attention being paid to the safety lamps, which should be carefully examined before the beginning, and at intervals during the progress of the work, to see that the gauzes are clean and that the lamps are in good working condition. The lamps should not be taken forward into the body of the gas, but should be placed in a safe position back of the workmen and where they will be protected from the gas. The work should not be carried forward too rapidly, but time should be allowed for the gas to drain off after setting each post and extending the brattice. The work should be carried forward in this manner to the face of the entry. As soon as the body of gas has been removed, a break-through should be cut in the pillar at a point as near the face as practicable. The brattice may then be taken down after closing all but the inside break-through, or if the gas is issuing in such quantities at the face of the entry as to require better ventilation than is afforded by this last break-through, the brattice used previously should be extended from the outby rib of the last break-through, toward the face of the entry, and maintained as close to the face of the entry as possible.

PREVENTION OF ACCUMULATIONS OF GAS IN MINE WORKINGS

Ques. 390.—In driving entries where large volumes of gas are given off, what precautions would you adopt to insure the safety of the workmen, and how would you prevent an accumulation of gas at the faces of the same? *B.—Pa. (B)*

Ans.—Use safety lamps only, and keep a sufficient volume of air in circulation to dilute and carry off all the gas as it is generated. The current should be well conducted to the face, and in order to accomplish this a brattice should be erected, if necessary, extending from the outby rib of the last break-through and running along one side of the entry toward the face, so as to compel the air-current to circulate around the end of the brattice and sweep the face, as shown in Fig. 1. Strict regulations should be made and enforced with regard to blasting; each shot should be well cut and mined before it is fired, and care should be taken that the charge is not located on the solid, but is given opportunity to work. All shots should be fired by an experienced miner duly authorized to do this work, and no shot should be fired except after a careful examination of the face to ascertain that there is no accumulation of gas at that point, and that a sufficient volume of air is passing. No accumulations of fine dust or coal should be allowed at the face of the entries. After the firing of each shot, the miners should use great caution in approaching the face to avoid the danger that may exist in case a body of gas has been set free or a gas feeder opened by the blast. Every precaution must be used to secure the roof of the entry, especially when the gas is coming from the roof. In case the gas is issuing from the coal, proper precautions must be taken to avoid falls of rib coal caused by the pressure of the gas.

Ques. 391.—In driving headings and narrow work into the solid coal in a mine generating explosive gases, what are the requirements of the Bituminous Mine Law of Pennsylvania?

I.—Pa. (B)

Ans.—Art. 6, Sec. 3, of the Bituminous Mine Law requires that no room, entry, airway, or other working place shall be driven a distance greater than 35 yd. in advance of the air, and no room shall be turned off from an entry at a point in advance of the air or inside of the last break-through.

Ques. 392.—In driving entries or other places where much explosive gas is being given off, what precaution would you use to secure the safety of the men working therein? State fully.

B.—Pa. (B)

Ans.—Such entries or places should be ventilated by a plentiful current of pure air, which should be made to sweep the face. The place should be carefully examined by a responsible fire-boss previous to the men beginning work. Care should be taken in the driving of such entries or places to see that the air-current is conducted properly to the working face by using a temporary brattice to throw the air forwards from the last break-through or cross-cut, see Fig. 1. This is especially necessary if the places are being driven to the rise, in order to avoid an accumulation of gas at the face. Safety lamps only should be used. Break-throughs should be made at such distances, within the limits required by law, as will insure good ventilation at the face.

QUES. 393.—In driving entries where large volumes of gas are generated, what precautions would you adopt to insure the safety of the men; how far would you drive the entries between break-throughs; and how would you prevent an accumulation of gas at the faces of the same? *B.—Pa.* (*B*)

ANS.—Use safety lamps only and keep the air up to the face. Entries should be driven in pairs, and break-throughs should be made between the entries at distances varying according to the conditions, from 16 to 35 yd. apart; as the Bituminous Mine Law specifies 16 yd. as the least distance and 35 yd. as the greatest distance allowed between break-throughs. When a new break-through is made at the face of the entry, the next one outby from this should be closed by a well-built air-tight stopping. In a very gaseous seam, or where a large gas feeder has been tapped at the face of the heading, it is often necessary to carry a line of brattice from the last break-through toward the face, to cause the current of air to sweep the face. In no case, should rooms be turned on an entry inside of the last break-through. The entries should be well timbered close to the face, especially if the roof is weak and contains gas. The face of the entry should always be carefully examined for gas and falls of roof, before each shift.

GAS ACCUMULATIONS OVER FALLS

QUES. 394.—If you were the foreman of a mine generating gas, and an accumulation of firedamp had collected on the falls, what method would you adopt to remove it? *F.—Pa.* (*B*)

ANS.—An ample air-current should be maintained in circulation at these points, and if necessary for the removal of the gas on the falls, a temporary brattice should be erected to deflect the air-current so as to sweep away the accumulated body of gas. A bore hole is sometimes put down from the surface to the fallen area and the gas allowed to drain off through this hole.

QUES. 395.—In a mine where pillars are being drawn, the fire-boss reported in the morning he could detect gas high up on the falls, but during the day gas was discovered where the men were working at the face; what, in your opinion, is the cause, and how would you proceed to secure the safety of the men and to remove the gas? *B.—Pa.* (*B*)

ANS.—The increase of gas is probably due to a fall in barometric pressure, causing a more free emission of gas, and an expansion of the body of gas already accumulated high up on the falls. The quantity of air in circulation in the mine should be increased if possible, but if this is not possible, or if the gas continues to increase and approach the working face

in dangerous quantities, the miners should be promptly withdrawn from the mine until the gas can be controlled and the workings again made safe.

Ques. 396.—In mining out pillars where gas is found on the falls, how would you conduct an air-current to remove the gas, and what precaution does the law require to be used in such cases? *B.—Pa.* (*B*)

Ans.—A plentiful supply of air should be made to sweep the edges and accessible parts of the falls in pillar workings, and the law requires the fire-boss to examine all such places frequently.

Ques. 397.—In case of an accumulation of explosive gas on falls in worked-out portions of the mine, which could not be removed, how should the ventilation be conducted to secure safety? *B.—Pa.* (*B*)

Ans.—The presence of such an accumulation of gas in abandoned workings is always an element of danger, and the condition of such abandoned workings should be carefully watched until an opportunity is afforded for the removal of the gas. This should be accomplished at the earliest possible moment, and only when the men have been withdrawn from the mine. In case it is impracticable to remove the gas by means of deflecting the air-current into such abandoned workings, some other means of removing the gas by bore holes, pipes, or otherwise, must be devised to prevent accident from the gas being thrown out on the entries by a sudden fall of barometer. The effectual sealing of abandoned workings is a difficult matter. It is possible, however, to avoid an accident from the escape of the gas into the workings, by building a line of air-tight brattice along the entry skirting the abandoned portion of the mine, after having sealed, as thoroughly as possible, the openings to the abandoned workings. What gas is then thrown out through the stoppings will be conducted behind the brattice to the foot of the upcast shaft, or discharged into the main return current at a safe point. A sufficient air-current should be kept continually in circulation behind the brattice to insure this. By means of valves in the stoppings, the discharge of gas from the worked-out portion of the mine can be controlled; and by means of suitable piping it can be led directly to the return air-course, or else discharged into the main current at night or other times when there is least danger to the men in the mine.

Ques. 398.—If you had charge of a mine where an abandoned part gave off a large quantity of carbon dioxide, how would you keep it from mixing with the air distributed in the working parts of said mine? *F.—Pa.* (*B*)

Ans.—The abandoned rooms should be sealed off by building substantial brick stoppings at the mouth of each room; and, if necessary, these stoppings should be plastered with fireclay. If there is any connection from such

abandoned workings extending to the surface, either by means of a crevice or an old opening, it will be found of advantage to adopt the blowing system of ventilation in preference to the exhaust system; as by this means the gases in the abandoned portion will be driven outwards to the surface, instead of being drawn into the mine airways.

QUES. 399.—How would you work a mine to prevent the accumulation of firedamp in the worked-out and abandoned parts thereof? *B.—Pa. (B)*

ANS.—The method adopted should be such as to reduce the amount of standing area to a minimum. Pillars should be drawn back and the roof allowed to fall in as quickly as the rooms reach the limit. All abandoned areas still remaining open should be ventilated by a separate current of air returning directly into the main return airway and passing out of the mine. Care should be taken to protect the main airways from contamination with the return air of the abandoned workings.

QUES. 400.—When are gobs most dangerous? *B.—Pa. (B)*

ANS.—The gobs of the mine become most dangerous when they are not thoroughly ventilated, thus furnishing a place for the accumulation of standing bodies of gas, and when gas occurs in the roof and is set free in large quantities by roof falls. The gobs are also dangerous when, on account of the storage of the fine coal and slack in the waste, gob fires are a frequent occurrence. Some coals have a greater tendency to heat and fire when stored in the gob than others. Gobs may also be considered dangerous when they are full of standing timber and the roof is strong. An undue pressure is thereby thrown on the entry pillars and stumps that may induce creep. All standing timber should be removed from abandoned workings so as to induce a fall of roof.

QUES. 401.—How would you remove gas from gobs? *I.—Pa. (B)*

ANS.—The best and most practicable method of draining accumulated gas from the gob or waste places in the mine workings, is to bore holes from the surface into the mine at points located in the gob where gas accumulates. The gas will readily rise through these holes to the surface where the mine is ventilated by a blower. This method has proved very successful where it has been tried; it is cheap and effective.

QUES. 402.—Should a fall occur on the main intake airway, and a large amount of marsh gas be given off from the roof, what steps would you take to prevent an explosion and rescue the men at work inside? *B.—Ind.*

ANS.—The men in the district in which the fall occurred should be at once notified and withdrawn from the mine by the return airway. All open lights should be at once extinguished. The ventilation of the mine should be increased at once, by speeding the fan or, if possible, by throwing

all the air into this airway after withdrawing the men from the other parts of the mine. In some particular cases, the current might be reversed to draw the gas from the mine, but this would not be possible under general conditions in mine workings, nor is it to be advised at all in any extended working.

QUES. 403.—What are the requirements of the Anthracite Mine Law in a case where it is found impracticable to keep the mine free from an accumulation of gas or water? *F.—Pa. (A)*

ANS.—The Anthracite Mine Law (Art. 10, Sec. 5) specifies that the mine inspector must be immediately notified whenever it is found impracticable to keep the entire mine free from an accumulation of gas or water.

PILLAR DRAWING

QUES. 404.—What particular dangers are there in pillar drawing in a mine giving off explosive gas? *B.—Pa. (B)*

ANS.—The drawing of pillars causes a rapid settlement of the roof strata, and often produces heavy falls of roof. If the gas generated in the mine comes from the roof, the drawing of pillars will result in the giving off of increased amounts of this gas when falls of roof occur. When the gas is contained in the coal, there is not the danger that would otherwise be present in pillar drawing, since it will have largely drained off before the pillars are drawn. If the gas is present in the floor or underlying strata, it will be set free when drawing pillars, but not in as large quantities as when present in the roof strata. The pressure of the gas when contained in the overlying strata often renders the roof slate heavy.

QUES. 405.—Where and under what conditions, in pillar workings, would you expect to find the largest quantity of explosive gas being generated? *B.—Pa. (B)*

ANS.—It is difficult to give a positive answer to this question, without knowing the location of the occluded gas; whether in the coal seam itself, or in the overlying or the underlying strata. The largest quantities of gas are always given off in the first working of a coal seam, where the gas exists in the seam itself. If, however, the gas is contained in the roof strata, the largest quantity of gas will undoubtedly be liberated, when the roof begins to fall. The gas liberated from the coal in pillar workings will decrease in quantity the longer the pillars are allowed to stand.

DRIVING TOWARD ACCUMULATIONS OF GAS OR WATER

QUES. 406.—What precautions does the Anthracite Mine Law require when driving toward old workings liable to contain gas or water? *F.—Pa. (A)*

ANS.—General rule 15, of the Anthracite Mine Law of Pennsylvania, provides that whenever a place is likely to contain a dangerous accumulation of gas or water, the workings approaching such place shall not exceed 12 ft. in width, and there shall be constantly kept at a distance of not less than 20 ft. in advance of the face at least one borehole near the center of the working and sufficient flank boreholes on each side.

OUTBURSTS OF GAS

QUES. 407.—State the causes of sudden outbursts of gas in coal mines, and what, in your opinion, should be done to prevent accidents from this cause? *F.—Pa.* (*A*)

ANS.—The occluded gases of coal seams and overlying and underlying strata often exist under great pressure. The removal of the coal as the workings advance leaves this pressure unsupported, and the gas issues from the face of the coal in large volumes; where feeders or pockets of gas exist, sudden outbursts may occur from a fall of roof or coal caused by the pressure of the gas. At times, this pressure is so great as to throw the coal violently down from the face or the rib of the workings. An outburst of gas from the floor or roof is often caused by a squeeze. A large increase in the quantity of gas in the mine workings frequently occurs from a sudden fall in the barometer, or a heavy fall of roof in the gob, but this can hardly be termed an outburst. Gaseous seams where sudden and violent outbursts are liable to occur should be drained, as far as practicable, by bore holes, through which the gas can escape to the surface. The bore holes are sometimes sunk from the surface, ahead of the workings; or, when the gas occurs in the roof or floor, holes are drilled in the entries, up or down, to tap the gas, and by relieving the pressure prevent an outburst and a heavy fall of roof, or the heaving of the floor. In the working of such coal seams, safety lamps only should be used and every precaution should be taken to timber the place securely.

QUES. 408.—What precautions would you adopt to prevent loss of life and property in mines subject to sudden outbursts of carbureted-hydrogen gas? *F.—Pa.* (*A*)

ANS.—An ample ventilating current should be maintained; the ventilating apparatus should be of the most improved type of centrifugal fan, and duplicate fans and fan engines should be installed to be used alternately, or together if the occasion demand. Open lights cannot be used with safety in this mine, and none but the most approved pattern of safety lamp should be employed, capable of giving the best light and indicating the gaseous condition of the mine air. Other precautions necessary to reduce the liability to accident from the cause mentioned will depend on the character of the roof, floor, and coal, and the manner of occurrence of the gas. When the gas occurs in the roof or floor, it is often necessary to reduce the width of the opening and to exact a more rigid and thorough inspection of the

timbering both as to the quantity of timber used and the manner of placing the timbers. Gas feeders in the roof often cause serious and heavy falls. The danger from this cause may sometimes be lessened by tapping the gas by means of drill holes put up in the roof or sunk in the floor, at regular intervals Another necessary precaution to be taken is the maintenance of a good supply of water throughout the mine, which can be used promptly to extinguish the gas when accidentally fired at the face.

QUES. 409.—If you were in charge of a mine and a large outburst of gas were to take place when all the men were at work, state what would be your first consideration to prevent an explosion.
B.—B. C., Canada

ANS.—The men should be notified at once and withdrawn from the return current, commencing at the point where the outburst of gas occurred. All open lights should be extinguished at once, as the men are notified, and they should be instructed to withdraw promptly from the mine. Steps should then be taken to gradually increase the circulation in the affected district, so as to dilute and render harmless the gas thrown into the workings. Only experienced men should be employed in the work of removing the gas, and reliable and experienced men should be stationed at each point of access to the affected district to prevent men from entering the return current. The work should be carefully watched to note the progress made in the removal of the gas. It may be expedient in the event of a very large outburst of gas, to remove all the men from the pit before any steps are taken to increase the circulation in the affected district. The work of removing the gas requires the utmost caution.

QUES. 410.—If you were in charge of a mine where safety lamps were used, and an outburst of gas took place, what would be your duty under such circumstances? *F.—Pa. (B)*

ANS.—The men working inby from the point where the outburst occurred and on the return of such air split, should be promptly notified and withdrawn by the safest road possible, all open lamps being at once extinguished. In furnace ventilation, the furnace fire should be extinguished at once After the withdrawal of the men from the mine, all the entrances should be fenced off and guarded, and the work of removing the gas begun by gradually increasing the circulation in the affected portions of the mine.

SHAW GAS TESTER

QUES. 411.—Explain the action of the Shaw gas tester.

ANS.—The *Shaw gas machine* is used to determine the percentage of marsh gas present in a sample of mine air contained in a rubber bag. To a graduated beam operated by a crank and connecting arm, are attached the pistons of two pump cylinders. The larger of these cylinders is fixed

in position at the end of the beam and pumps a fixed quantity of pure air into the combustion chamber, at each stroke; the smaller cylinder is movable along a slide graduated to correspond to the graduations of the beam. This cylinder can be changed and set in such positions as to pump any desired percentage of gas into the combustion chamber, while the larger cylinder is pumping pure air into the same chamber. By trial, the lowest explosive point for any gas is first determined, as made known by the ringing of a gong, caused by the reaction of the explosion in the chamber, against a movable piston that strikes the hammer of the gong. Having thus determined the lowest percentage of this gas that is explosive, the bag containing the mine air is now attached to the large cylinder which is thus made to pump mine air instead of pure air. If the mine air contains a little gas, the gong will ring loudly and the small cylinder is then set back until ringing ceases. The amount the small cylinder is thus set back shows the percentage of gas in the mine air.

CHAPTER IV

SAFETY LAMPS

ESSENTIAL FEATURES OF A SAFETY LAMP

QUES. 500.—What is a safety lamp? Why is it safe?

F_2.—Ala.

ANS.—A safety lamp is a lamp designed to give light in an atmosphere charged with gas, without igniting the gas.

The safety lamp, when properly handled, gives a certain amount of security in presence of gas because the gauze surrounding the flame does not permit the passage of the flame as long as it is kept clean and cool.

QUES. 501.—What constitutes a good safety lamp?

F.—Pa. (A)

ANS.—A good safety lamp for general work must give a good light, be safe in strong currents of air, must not be too sensitive to gas, and should be provided with a good lock fastening and a lighting appliance by which the lamp may be relighted without opening, when extinguished. The lamp should be self-extinguishing in an explosive atmosphere. It should be simple in construction and easily taken apart and cleaned, and as light in weight as is permissible for the required strength. A good lamp for testing should be sensitive to the presence of small percentages of gas, should maintain a uniform flame, and should have a free admittance of air at a point below the flame. All safety lamps should have a good picker by which the wick can be cleaned when necessary.

QUES. 502.—What are the essential features of a safety lamp?

B.—Ind.

ANS.—The essential features of a good safety lamp depend on the use for which the lamp is intended. Safety lamps are used for two purposes: (1) for the detection of gas in the workings; (2) for general work in gaseous mines. The essential features of a lamp used for testing are: (*a*) sensitiveness to the presence of a small quantity of gas in the air-current; (*b*) a uniform flame, and a free admission of air into the lamp below the flame. For the purpose of testing, the Davy lamp has been the favorite among fire-bosses, because the flame cap forms more readily in this lamp owing to the

free admission of air into the lower part of the gauze below the flame, and also because of the free circulation of air and gas within the gauze, making it extremely sensitive to the presence of gas. The Davy lamp, however, is not a safe lamp for general use in mine workings, on account of its liability to flaming in the presence of gas, and also on account of the danger of the flame being blown through the gauze by a strong current of air. The essential features of a good lamp for general use at the working face, are: (*a*) diffusion of light and good illuminating power; (*b*) security of lock fastenings; (*c*) protection from air-currents by a bonnet; (*d*) freedom from smoking; (*e*) protection against internal explosion in the lamp; (*f*) ability to relight the lamp without opening it, when it has been extinguished from any cause; (*g*) protection against the breaking of the glass of the lamp by flying coal or other accident. The diffusion of the light is attained by the use of a glass globe surrounding the flame. The smoking of a lamp is largely prevented by a good draft, as accomplished by the Mueseler sheet-iron tube inside the lamp, which increases the draft. Internal explosions are guarded against by a bonnet or, as in the Marsaut lamp, by multiple gauzes, one inside of the other. The Wolf lamp is provided with a device for relighting the lamp without opening it, consisting of a percussive igniter. This feature is of great value in case of an explosion, as the lamps are always extinguished by the force of the blast, and if they cannot be relighted at once, many of the men become confused and lost in the afterdamp before they can find their way to a place of safety.

QUES. 503.—Name six essential features of a good safety lamp for general work. *I.—Pa.* (*B*)

ANS.—(1) Maximum illuminating power; (2) safety in strong currents; (3) security of lock fastenings; (4) simplicity of construction; (5) ability to relight the flame, when extinguished, without unlocking the lamp; (6) the entry of the air into the lamp below the flame, thereby decreasing the tendency of the lamp to smoke, and improving its illuminating power by securing a better draft—by this means the conditions for producing a good flame cap in testing for gas are also improved.

PRINCIPLE OF THE SAFETY LAMP

QUES. 504.—Who was the inventor of the common safety lamp? *E.—Ill.*

ANS.—Sir Humphrey Davy is generally conceded to be the inventor of the safety lamp in its essential principle, which is the isolation of the flame from the outside atmosphere by means of a wire gauze.

QUES. 505.—Explain the principle discovered by Davy, and embodied in the safety lamp. What is the standard size of wire gauze used in the Davy lamp? *B.—B. C., Canada*

Ans.—The principle of the safety lamp, discovered by Sir Humphrey Davy, is the isolation of the flame of the lamp from the outer air, afforded by the wire gauze of the lamp. The inflammable mixture of gas and air passes through the gauze and burns within the lamp. The burning gas, in passing out through the gauze, is divided by the mesh of the gauze into fine streamlets of gas; its temperature is lowered by the cool wire gauze below the temperature of ignition of the gas, and the flame thereby extinguished. As long as the wire gauze remains cool, the flame is prevented from passing outside of the lamp; the gauze, however, permits the free passage of the air and gas into and out of the lamp.

The standard wire gauze employed is a mesh containing 28 parallel wires per inch, forming 784 holes per square inch.

Ques. 506.—Why will flame not pass through the gauze if the lamp is carried carefully? *F_1.—Ala.*

Ans.—Flame will not pass through the gauze of a safety lamp under ordinary conditions, because the burning gases, in passing through the cool gauze, are reduced in temperature below the point of ignition; it is possible, however, for a sufficient velocity of the air-current to force the flame through the gauze; and therefore great care must be taken to protect the lamp from high velocities in an explosive mixture. The gas burning inside of a gauze may raise the temperature of the wire forming the gauze to such a point as to transmit the flame and ignite the gas outside of the lamp.

PASSAGE OF FLAME THROUGH SAFETY-LAMP GAUZE

Ques. 507.—Are there any conditions under which the flame will pass through the gauze of a safety lamp? Explain fully. *B.—Pa. (B)*

Ans.—Flame will pass through the gauze of a safety lamp: (1) When the gauze becomes heated; its power to cool the burning gases below their temperature of ignition is then destroyed. (2) When the lamp is subjected to a current of air sufficient to blow the flame through the gauze; in this case, the passage of the flame through the small openings of the gauze is too rapid to cool the burning gas below its temperature of ignition. (3) When the gauze is dirty; in this case, the dirt, smoke, or soot accumulating on the wires of the gauze becomes a good conductor of heat and the wires are more rapidly heated, which destroys their power to cool the flame of the burning gas below its point of ignition.

Ques. 508.—Are there any conditions under which it would not be safe to use a safety lamp? If so, name them. *F.—Pa. (A)*

Ans.—The conditions that render a safety lamp unsafe are: (1) When the lamp is exposed to a velocity greater than, say, 450 ft. per min., or a

velocity that will blow the flame against the gauze of the lamp. (2) When the lamp is exposed for some length of time to a percentage of gas that will cause flaming. (3) When the gauze is dirty, or defective by the wires becoming separated from one another. (4) When the lamp is in the hands of an inexperienced person.

QUES. 509.—In what velocities of air-currents do the representative safety lamps that are used in the mines become unsafe? *I.—Pa. (A)*

ANS.—The common unbonneted Davy is unsafe in a gaseous current having a velocity greater than 6 ft per sec. or 360 ft. per min. The unbonneted Clanny is unsafe when the velocity of the current exceeds 480 ft. per min. The Geordie lamp is considered safe in a current velocity of 1,000 ft. per min. The bonneted Clanny, in good condition, may safely be exposed to a current velocity of 2,000 ft. per min. when no dust is present in the air, and cases are recorded where this lamp has been safely exposed to a current having an even greater velocity than this. The quantity of dust suspended in the air-current and also the percentage of gas present rapidly reduce the current velocity to which any lamp may be safely exposed. The Marsaut and Mueseler types of lamps will safely stand somewhat higher velocities than the bonneted Clanny. It may be generally stated, however, that under ordinary mining conditions the bonneted lamps of any type should not be exposed to a gaseous current having a velocity greater than 2,000 ft. per min., and where dust is present in the air, or where the percentage of gas is high, the permissible velocity should not exceed, say, 1,200 or 1,500 ft. per min.

QUES. 510.—What are the advantages obtained from having safety lamps shielded? *B.—Pa. (B)*

ANS.—The purpose of a shield or a bonnet is to protect the flame of the lamp from strong currents of air, or from the quick movement of the lamp itself in a slow air-current. The shield also provides security against internal explosions of gas that occur at times in the lamp. There is also an additional advantage in the use of a bonnet or shield in the more complete isolation afforded in the upper portion of the lamp by the confining or restricting of the outflow of the products of the combustion in this portion of the lamp. The increased percentage of carbon dioxide in the upper portion of the lamp renders the firedamp less explosive, although this last is an incidental advantage growing out of the use of the shield.

QUES. 511.—What precautions should be taken in the use of safety lamps in gaseous mines? *B.—Pa. (B)*

ANS.—In the use of safety lamps, it is always necessary to keep the gauze and lamp clean; the lamp should be examined carefully and locked before it is taken into the mine. Care should be taken not to swing the lamp, and not to expose an unbonneted lamp to a current of air moving

with such a velocity that the flame will be blown on to or through the gauze. The unbonneted Davy is unsafe in a current having a velocity greater than 6 ft. per sec.; the unbonneted Clanny, in a current having a velocity greater than 8 ft. per sec. When moving against the current, it must be remembered that the velocity with which the air strikes the lamp is equal to the sum of the velocity of the current and the velocity with which the lamp is moving against the current. When working in gas, it is necessary to carefully observe the safety lamp and to extinguish it at the first sign of the heating of the gauze. When gas is observed in the lamp, and especially if the lamp fills with flame, it is necessary to lower and remove the lamp with great care and promptness, making no quick movement lest the flame of the gas burning in the lamp be blown through the gauze.

EXPLOSIONS INSIDE A SAFETY LAMP

QUES. 512.—Why does firedamp explode in a safety lamp without producing an explosion of the gas with which the lamp is surrounded? *F_1.—Ala.*

ANS.—As long as the gauze remains cool, the flame of the gas burning or exploding within the lamp is prevented from passing outside. The burning gas, as it attempts to pass through the gauze, is divided into numerous little streamlets of gas that are at once cooled below the point of ignition of the gas by contact with the wire of the gauze, and the flame is thereby extinguished as the gas passes through the gauze. The force of the explosion within the lamp may, however, be so great as to force the flame through the gauze and ignite the gas outside of the lamp.

QUES. 513.—Is it possible that an explosion in a safety lamp could be of sufficient force to pass the flame through the gauze? Explain fully. *B.—Pa. (B)*

ANS.—An explosion of gas within a safety lamp may be of sufficient force to pass the flame through the gauze. The gauze of the lamp affords protection, and prevents the passage of the flame only when the following conditions are observed: (*a*) the gauze must be kept clean and cool; (*b*) the lamp must not be subjected, either inside or out, to a rapid current of air due to an excessive pressure that will drive the flame through the gauze.

QUES. 514.—If an explosion should occur in the lamp, what would you do? *F_1.—Ala.*

ANS.—An explosion occurring in the lamp, no quick movement should be made, but the lamp should be promptly but slowly and carefully removed from the body of gas, to avoid as far as possible the danger of passing the flame through the gauze. This requires presence of mind on the part of the one holding the lamp.

CONSTRUCTION OF SAFETY LAMP

Ques. 515.—Explain the construction of the ordinary safety lamp. *F.—Pa. (A)*

Ans.—The Davy safety lamp consists of a solid brass oil vessel, to which is attached a gauze cylinder, 5½ in. high by 1½ in. in diameter, closed at the top. The gauze chimney is held firmly in position by three brass rods, called the standards; to the upper ends of the standards are attached a brass ring and cap. The gauze mesh contains 784 openings to the square inch, made by 28 parallel wires crossing one another. The gauze cylinder is surmounted by a gauze cap completely enclosing the flame of the lamp, the cap increasing the height of the lamp to 6 in. This cap affords double protection at the top where the gauze is most liable to be burned through, or to become hot and pass the flame. The Davy lamp was the first practical safety lamp for mining use at the working face, and is still the favorite lamp for testing for gas, as it gives a good flame cap. The lamp admits air freely below the flame, has a good draft, and does not smoke. It flames readily, however, in gas and the gauze heats, making it an unsafe lamp for general purposes.

Ques. 516.—How many apertures are there in a square inch of the standard safety-lamp gauze? *F_1.—Ala.*

Ans.—The standard lamp gauze has $28 \times 28 = 784$ apertures per square inch; this is the standard for safety lamps as fixed by Davy after he had ascertained by experiment that flame would not pass through such sized apertures.

Ques. 517.—What is a safety lamp, and how is it made or constructed? *F_1.—Ala.*

Ans.—A safety lamp is a lamp whose flame is protected by a wire gauze that completely isolates it from the surrounding air. It consists of a brass oil vessel to which is attached the wire-gauze cylinder surrounding the flame; the closed top is further protected by a gauze cap. In some lamps, the lower portion of the gauze is replaced by a glass cylinder to increase the illuminating power of the lamp.

Ques. 518.—What are the essential parts of a safety lamp? *F.—Pa. (A)*

Ans.—The essential parts of a safety lamp are: the oil vessel, the gauze or gauzes, the glass cylinder, the bonnet, the inner chimney of the Mueseler lamp, the various forms of deflectors, where used, and the port holes for the entry of air into the lamp, together with the frame or standards that bind the different parts together, and the lock that prevents the untimely opening of the lamp.

TYPES AND COMPARISON OF SAFETY LAMPS

QUES. 519.—Describe the Davy, Clanny, and Wolf safety lamps, and the purposes to which each is best adapted. *F.—Pa.* (*A*)

ANS.—The Davy lamp consists of a solid brass lamp or oil vessel, to which is attached, by means of three brass rods or standards, a gauze cylinder, 5½ in. high by 1½ in. in diameter, and closed at the top. The gauze mesh contains 784 openings to the square inch, made by 28 parallel wires per inch crossing one another. This gauze is surmounted by a gauze cap completely enclosing the flame of the lamp, the cap increasing the height of the gauze chimney to 6 in. This cap is double at the top where the gauze is most liable to be burned through, or to become hot and pass the flame. The Davy lamp is best adapted to the purpose of testing for gas.

The Clanny lamp is a modification of the Davy, the lower part of the gauze being replaced by a glass chimney that permits a better light than is given by the Davy. The disadvantage of the Clanny lamp, however, lies in the fact that the air enters the lamp through the lower part of the gauze, above the glass chimney, and must descend to the flame, before it ascends and passes out through the upper part of the gauze. This causes a conflict between the descending and ascending currents around the flame, and results in the smoking of the lamp. The flame is also not as sensitive to gas as the flame of the Davy lamp. The Clanny lamp, when supplied with a sheet-metal covering to the gauze chimney, called a *bonnet*, is an excellent lamp for general work.

The Wolf lamp is an improved Clanny. Naphtha (benzine) is used in this lamp instead of the ordinary oil, which improves the light and gives a more uniform flame and a better flame cap. The lamp, when extinguished by accident, may be relit without unlocking, by means of a friction igniter. The naphtha, in burning, produces much less smoke than the common oil used in other safety lamps. This is a good lamp for general use; it is locked by means of a magnet lock that can only be unlocked by means of a powerful magnet in the lamp room.

QUES. 520.—Name and describe several of the most important modern safety lamps. Explain the advantages claimed for them over the Davy lamp. *I.—Pa.* (*A*)

ANS.—The Davy lamp has been described and its advantages and disadvantages given in answers to Ques. 515 and 519. The Clanny and the Wolf lamps have been described and their advantages given in the preceding question. The Mueseler lamp differs from the Clanny by the introduction of a sheet-iron chimney inside the lamp, which increases its draft and illuminating power by bringing the entering air closer to the flame. The Hepplewhite-Gray lamp is a particularly good lamp for mine use for several reasons. The glass chimney is made conical, diffusing the light upwards, which greatly assists the inspection of the roof. The air can also be made to enter the top of the standards and to pass down the standards, entering

the lamp below the flame. By this means, a thin stratum of gas at the roof is easily detected without tilting the lamp. The gauze of this lamp is bonneted.

QUES. 521.—Name and describe three safety lamps now in use. State which lamp you consider the best and safest, and why. In what does their safety consist? *F_1.—Ala.*

ANS.—Davy, Clanny, Mueseler.

The Davy lamp, described in answer to Ques. 519, is the best lamp for making an examination for gas, as it is more sensitive to gas than any other lamp. The flame of this lamp is surrounded by a cylinder of gauze having no glass; the lamp gives a poor light. The Clanny lamp has a glass cylinder surrounding the flame, and is better suited for general work, as it gives more light than the Davy lamp. The Mueseler lamp is the best of these three lamps for use in strong air-currents; the gauze is bonneted or protected, so as to prevent the flame from being blown through the gauze; the air is admitted through a gauze ring over the glass, and the products of combustion pass up through a funnel-shaped chimney enclosed inside of the gauze and pass out at the top.

All safety lamps depend on the principle explained in answer to Ques. 505; namely, the isolation of the flame by wire gauze; but this principle affords protection only when the lamp is properly handled by an intelligent person.

COMPARISON OF SAFETY LAMPS

QUES. 522.—Name and describe some of the important differences between the Davy lamp and other kinds of safety lamps. *B.—Pa. (B)*

ANS.—The Davy lamp, unlike many other safety lamps, admits air freely all around and below the flame. The result of this free admission of air below the flame is to produce a uniformly large flame cap when gas is present. The height of this flame cap is not reduced in the Davy lamp as it is in many other lamps by the particular construction of the lamp. Neither is the flame cap in the Davy exposed to conflicting currents as it is in such lamps as admit air at a point above the flame. The illuminating power of the Davy lamp is necessarily less than that of other safety lamps where the flame is surrounded by a glass chimney. The Davy lamp is not a good lamp for inspecting the roof or other portions of mine workings, but is particularly adapted to testing for gas in the workings.

QUES. 523.—Explain why the Davy lamp is used by fire-bosses, and the Clanny by workmen. *F.—Pa. (A)*

ANS.—The Davy lamp is more sensitive to gas, but the illuminating power of the Clanny lamp is much greater than that of the Davy lamp, and the glass chimney of the Clanny lessens the danger of the flame of the

lamp being blown through the gauze by a sudden draft, or by an accidental fall of the lamp. The flame of the Davy lamp is more sensitive to gas than that of the Clanny, because in the Davy lamp the air enters at a point below the flame and rising about the flame passes out of the upper portion of the gauze, thereby maintaining a better circulation in the lamp, causing less smoke, and producing a better flame cap. In the Clanny lamp, the air enters at a point above the flame and passes downwards to the flame and then upwards, escaping through the upper portion of the gauze. There are thus produced two conflicting currents inside the lamp, which cause the lamp to smoke easily and prevent the formation of a good flame cap.

QUES. 524.—Under what conditions may the Davy and Clanny lamps be lawfully used in gaseous mines? *B.—Pa.* (*B*)

ANS.—The Bituminous Mine Law (Art. 5, Sec. 6) permits the use of the Davy and Clanny lamps by mine officials to examine for gas, and the Clanny lamp is permitted for general use if protected with a shield. It is only the general use of the unprotected Clanny and the common Davy that is prohibited. What has come to be known as the Geordie lamp is a Davy lamp having a cylinder of glass inside of the gauze that not only protects the flame from strong currents of air, but prevents the heating of the gauze and renders the lamp safe; and as it is no longer a common Davy the lamp in this combination satisfies all the requirements of law.

QUES. 525.—What, in your opinion, is the best safety lamp? Describe it, and three others with which you are acquainted, and give reasons for your opinion. *M.—B. C., Canada*

ANS.—The best safety lamp is one that combines, as far as practicable, simplicity of construction, minimum weight, and maximum illuminating power, security against strong currents and explosions within the lamp, a suitable degree of sensitiveness to gas, a lock or fastening that cannot be opened in the mine and that will reveal any attempt on the part of the miner to tamper with the same, but that can be readily opened without failure at the lamp station. The lamp combining to the largest extent all of these qualities is the lamp best adapted for mining use. It is difficult to discriminate between the different types of safety lamps now being manufactured. The Hepplewhite-Gray lamp combines to a marked degree many of the features mentioned. It is a modified Clanny lamp with bonneted gauze and conical glass chimney, allowing the upward diffusion of the light. This lamp is arranged to admit air below the flame, and by closing the lower openings in the standards, air may be drawn from above the lamp for the detection of a thin layer of gas at the roof.

Some of the forms of the modified Davy lamp, such as the Evan Thomas lamp, or the Hughes Deputy lamp, are efficient lamps for general use on account of their simplicity and utility for general work in the mine. One form of the Evan Thomas lamp is provided with a double glass chimney; the entering air is conducted downwards between these chimneys, cooling the glass, and, it is claimed, increasing the illuminating power of the lamp and

entering the lamp below the flame. In another form of this lamp designed for testing, the inner glass chimney is replaced by a gauze that surrounds the flame. The Hughes Deputy lamp is similar to this form of the Evan Thomas lamp, except that the glass cylinder surrounding the lower portion of the gauze is made to slide upwards when desired. The Wolf lamp possesses some special features; namely, a magnet lock that cannot be opened in the mine, and a possibly greater illuminating power by the use of naphtha (benzine) instead of the ordinary sperm oil. The lamp, though burning a special oil (naphtha), is a good lamp for general mining work. It is claimed that it will readily show the presence of 1 per cent. of gas, and with care the experienced miner can detect the presence of $\frac{3}{4}$ per cent. of gas in the air.

QUES. 526.—What kinds of safety lamps have you used in places where firedamp was known to exist? Which lamp do you prefer, and why? *B.—Ind.*

ANS.—This question requires a statement of personal experience and an expression of personal opinion.

QUES. 527.—With what safety lamps are you familiar? Explain the principle and construction of the lamps that you have used, and state which, in your opinion, is best to test for gas. Which is the best lamp to work with? State fully. *F.—Pa. (A)*

ANS.—The lamps in common use in the anthracite region of Pennsylvania are the Davy, Geordie, Clanny, Evan Thomas, Hughes Deputy, Hepplewhite-Gray, and Wolf lamps. These lamps have all been briefly described in answer to Ques. 519, 524, and 525.

The favorite lamp for testing for gas is the Davy lamp protected by a movable metal shield or a sliding glass cylinder.

The best working lamp should combine, as far as practicable, simplicity of construction, minimum weight, maximum illuminating power, security against strong currents and explosions within the lamp, a suitable degree of sensitiveness to gas, and a secure lock or fastening that will reveal any attempt to tamper with the same.

QUES. 528.—Are there any safety lamps that you know of as sensitive to gas as the Davy? *B.—Pa. (B)*

ANS.—None of the ordinary forms of safety lamp are as sensitive as the Davy. Special lamps have been constructed to burn alcohol, naphtha, or hydrogen, for the purpose of producing a more sensitive, non-luminous flame better adapted to observing the height of the flame cap in testing for gas. Such lamps are the Pieler and the Stokes lamps, burning alcohol, the Clowes hydrogen lamp, and the Wolf lamp, burning naphtha (benzine). It is claimed that the Wolf lamp, burning naphtha, will detect $\frac{3}{4}$ per cent. of marsh gas. The common Davy lamp with the Beard-Mackie sight indicator attached, is probably the simplest testing lamp in use; with a normal working flame and with ordinary sperm or lard oil the indicator shows clearly the presence of $\frac{1}{2}$ per cent. of gas. The indicator consists of a series of

platinum wires supported on a frame that is readily inserted in the wick tube of any lamp. The incandescence of the successive wires shows the percentage of gas present, as ½, 1, 1½, 2, 2½, and 3 per cent., respectively.

Ques. 529.—What principles are involved in the construction of a safety lamp that would render one lamp more sensitive in the detection of gas than another? *B.—Pa.* (*B*)

Ans.—A safety lamp that admits the air above the flame is not a good lamp for the detection of gas; inasmuch as the air is compelled to descend to the flame, after entering the lamp; and the descending and ascending air-currents, within the lamp, interfere seriously with the production of a good flame cap. A good lamp for testing will always provide for a free entry of air below the flame. Lamps burning hydrogen, alcohol, or one of the lighter oils, such as naphtha, have a non-luminous flame that permits the flame cap to be observed more readily than the flame from ordinary oil, unless used in connection with some form of sight indicator. There should be no reflecting surfaces behind the flame, as this interferes very much with the observation of the cap.

Ques. 530.—Explain why some safety lamps are more sensitive to gas than others. *B.—Pa.* (*B*)

Ans.—This is due to their construction. The Davy lamp is more sensitive than other lamps because it possesses such a large gauze surface, permitting the free admission of the gas-laden air. The Hepplewhite-Gray lamp is not so sensitive as the Davy, but is so constructed that it can detect gas nearer the roof than any other lamp. Other lamps will not burn where much gas is present, owing to the restricted circulation within the lamp retaining the products of the increased combustion in the top of the lamp until the flame is extinguished for lack of oxygen. This feature, however, does not indicate that the lamp is sensitive to gas, but rather the reverse.

Ques. 531.—What are the features that render some safety lamps more sensitive to gas than others? *B.—Pa.* (*B*)

Ans.—The features that render a lamp more sensitive to gas are: (1) A free entry of air and gas into the lamp at a point below the flame. (2) An unobstructed upward draft within the lamp sufficient for the removal of the products of combustion. (3) The maintaining of a uniform non-luminous flame, such as the hydrogen flame of the Clowes hydrogen lamp, or the alcohol flame of the Pieler lamp. (4) No reflecting surfaces behind the flame. Some safety lamps are more sensitive to gas than others because they embody a larger number of these features.

Ques. 532.—Under what conditions would you prefer to use a Mueseler safety lamp rather than a Davy? *E.—Ill.*

Ans.—The Davy lamp is unsafe for general work in a gaseous mine. The lamp is a favorite lamp with fire-bosses for making an examination for gas, on account of the sensitiveness of the flame to the presence of gas.

The unbonneted Davy lamp is not safe in a current of air containing gas and having a velocity exceeding 6 ft. per sec. As the percentage of gas in mine air nears the explosive point, the Davy lamp, owing to its sensitiveness and tendency to flame, is unsafe. The Mueseler lamp is a safer lamp to use in strong currents of air, or where the percentage of gas is liable to be increased, and there is a possibility of flaming and internal explosion of gas within the gauze of the lamp. The wrought-iron chimney within the gauze of the Mueseler lamp not only increases the illuminating power of the lamp by increasing the draft, but renders the lamp more secure against passing the flame when it is subjected to a current of high velocity or when introduced into a highly explosive mixture of firedamp. Under these conditions, the Mueseler is preferable to the Davy.

CARE OF SAFETY LAMPS

QUES. 533.—What instructions would you give in reference to the care and preparation of safety lamps before giving them to the workmen, and how would you instruct the workmen as to their use? *B.—Pa. (B)*

ANS.—Those in charge of the lamp room should be instructed to handle all lamps with special care when taking them apart and replacing the parts after cleaning; the gauze should be carefully examined and where defective it should be discarded at once. There should be attached to every lamp as it is received from the pit a check number or tag taken from a hook and indicating who had the lamp. The removal of the check from the hook will also indicate that the man is not in the mine. Each lamp is taken apart and carefully examined to see that it has not been tampered with or damaged, and then cleaned, filled, and trimmed in readiness for the next shift. The miner using the lamp should be instructed to keep the same in an erect position and avoid exposing it to a strong current, or moving the lamp too rapidly in any direction, especially against the air. He should understand that he is in no case to tamper with any part of the lamp, but if the light is extinguished he is to return it to the surface or to a lamp station to be relighted.

QUES. 534.—What care and attention should the safety lamps receive in the lamp room, and how should the lamps be inspected before they are passed over to the workmen for use? *F.—Pa. (B)*

ANS.—Each lamp, when received from the miner, should be hung on a hook having his number until it is taken down to be cleaned. The lamp is taken apart and the oil vessel refilled, the gauzes thoroughly brushed out and examined, and every part of the lamp rubbed bright and clean and carefully replaced, after which the lamp is again hung on its hook ready for use. When called for, the lamp is taken down, the oil vessel unscrewed, and its wicks lighted, and the lamp again screwed together, locked, and handed to the proper person, who also carefully examines it as he receives it. Safety lamps are sometimes tested by exposure to a gaseous atmosphere

before being given to the workmen. By this means defects are often made known that an examination would not reveal.

Ques. 535.—A lamp has been returned to the lamp room, and on cleaning it was found to have defects. How could this occur, and what would be your duty as mine foreman in such cases? *F.—Pa.* (*B*)

Ans.—The defects have been caused by accident, careless handling, or mischief and should in any case have been reported, if known, by the person who used the lamp. The case should be investigated at once and proper measures taken to avoid its recurrence. The lamp may have been injured by another person than the one who used it, either in a spirit of mischief or malice, and the defect may not have been noticed by the person returning the lamp; the mine foreman must use his best judgment and tact in such a matter.

Ques. 536.—What instructions would you give the workmen in the use of safety lamps, and what precautions would you take in the distribution of lamp keys within the mine? *F.—Pa.* (*B*)

Ans.—No person may be entrusted with a safety lamp until he has given satisfactory evidence to the mine foreman that he understands its proper use and the danger of tampering with the same (Bituminous Mine Law, Art. 20, Rule 57). The person receiving the lamp should be instructed to carry it erect, so that its flame will not touch the gauze, and to be careful not to expose the lamp to a strong current of air, or to break the glass or injure the gauze. In no case must he tamper with the lamp or attempt to relight it when extinguished; he must avoid placing the lamp in a position where the gauze can become clogged with dust; he must maintain a normal flame in the lamp; and when gas is observed in the lamp, he must carefully withdraw to fresh air. Lamp keys should be given only to persons duly authorized by law to receive them.

Ques. 537.—What dangers may arise from the improper care and handling of safety lamps by the workmen? *F.—Pa.* (*B*)

Ans.—There is danger of the gauze becoming dirty or clogged with dust, which would render it more liable to pass the flame. A lamp exposed carelessly to a strong air-current may have its flame blown through the gauze. When the lamp is not held in an erect position, the gauze may become heated and pass the flame. The glass of the lamp may be cracked by too large a flame, or by water dropping from the roof. The greatest danger exists when the lamp is brought in contact with a body of gas, unless the person handling the lamp has the presence of mind to remove it from the gas promptly and carefully avoid any quick motion.

Ques. 538.—If, on going your rounds through the pillar workings of a gaseous mine, a miner's safety lamp appears cleaner on

your second visit than it did on your first visit, what would you think was wrong, and what would be your duty in such a case?

B.—Pa. (*B*)

ANS.—The circumstances would indicate that the miner had cleaned his lamp, and the fact would require an investigation as to how this was done. If sufficient evidence could be obtained that the miner had tampered with the locked fastenings of the lamp, the case should be promptly reported to the mine foreman.

QUES. 539.—As fire-boss, what would be your first duty on arriving at the lamp house in the morning? *B.—Pa.* (*B*)

ANS.—To carefully examine my lamp and light it before starting on my rounds.

HEIGHT OF FLAME CAP

QUES. 540.—How would you examine the various safety lamps in common use, as to their safety for testing for gas, also for general work? What appearance has the flame of the lamp when brought in contact with various mixtures of an explosive character?

M.—B. C., Canada

ANS.—When making an examination of the different types of safety lamps for the purpose of comparing their utility and safety in testing for gas and in general work in the mines, the lamps should be subjected to a gaseous current at different velocities in such manner that their behavior may be observed with safety. Experiments of this kind have often been performed by placing the lamps in a box through which currents of different velocities and having known percentages of gas are passed.

The appearance of the flame in contact with various mixtures of explosive gas varies according to the kind of flame employed. The two flames usually employed for testing for gas are the normal flame and a small, uniform flame. When the common Davy lamp is used, the heights of the flame cap are best observed by using the small, uniform flame. The heights of the flame caps for different percentages of gas may be calculated approximately by the formula

$$h = \frac{J^3}{36}$$

in which h = height of flame, in inches;
J = percentage of gas in mixture;

thus, the height of the flame cap in a mixture containing 2 per cent. of gas is

$$h = \frac{2^3}{36} = .22;$$

or, for a mixture of 1 of gas to 18 of air (5.26 per cent.),

$$h = \frac{5.26^3}{36} = 4.04$$

Ques. 541.—If, in your examination for gas, you detected a cap 3⅜ inches high, what percentage of gas would you say was indicated by this cap? What percentage of gas is shown by each of the following caps: cap ⅝ inch high; cap ⅜ inch high; cap ¼ inch high? *I.—Pa. (B)*

Ans.—With the common Davy lamp, burning sperm or lard oil, the height of cap produced in any given percentage of gas will vary slightly with the original height of the flame used for testing. More uniform results are obtained with the common Davy when the flame is drawn down so low that its luminous tip disappears; but when testing in the mine this flame is very easily extinguished, and a slightly higher flame is generally employed, giving caps of less height and less easily discerned for the same percentage of gas. When using the smallest flame possible, the percentage of gas corresponding to any given height of flame cap is determined very approximately by the formula,

$$J = \sqrt[3]{36\,h}$$

in which J = percentage of gas present in the air;
h = height of flame cap, in inches.

Substituting the given values in this formula for each case given

For a ⅝-inch flame cap, $J = \sqrt[3]{36 \times .625} = 2.82$ per cent.
For a ⅜-inch flame cap, $J = \sqrt[3]{36 \times .375} = 2.38$ per cent.
For a ¼-inch flame cap, $J = \sqrt[3]{36 \times .25} = 2.08$ per cent.

The last two flame caps would hardly be discernible except by an experienced eye under the most favorable circumstances.

OILS FOR SAFETY LAMPS

Ques. 542.—What does the law require in regard to oils for illumination and lubrication in mines? *F.—Pa. (B)*

Ans.—No explosive oil shall be used or taken into the mine for lighting purposes except when used in approved safety lamps, and no oil shall be stored or taken into the mine in quantities exceeding 5 gallons. The oiling or greasing of cars in the mine is strictly forbidden, except the place where said oil or grease is used be thoroughly cleaned at least once every day. Not more than 1 barrel of lubricating oil shall be permitted in the mine at one time, and only a pure animal oil or cottonseed oil, or oils free from smoke shall be used for lighting. (Art. 8, Sec. 4.)

TESTING FOR GAS WITH SAFETY LAMPS

Ques. 543.—Describe the action of the flame of a lamp in a mixture of air and CH_4 and also in a mixture of air and CO_2. *F.—Pa. (A)*

ANS.—The flame of a safety lamp exposed to a mixture of air and marsh gas, CH_4, is increased in height and volume according to the percentage of gas present in the air. There is formed about and above the flame an envelope of burning gas and air. The gas burns with a pale-blue non-luminous flame that is not visible except as a pale-blue cap above the luminous flame of the lamp. As the percentage of gas is increased, and the mixture nears its explosive point, the flame becomes more voluminous and slight explosions take place within the lamp, the lamp often filling with flame. In case a normal flame has been used in testing for gas, the flame at this point assumes a waving spindle shape that rotates in a weird manner about the central axis of the lamp.

The flame of any lamp in presence of a considerable quantity of carbon dioxide, or blackdamp, CO_2, is depressed or diminished in size. This gas is incombustible. When the percentage of gas present is considerable, the flame of the lamp becomes very dim, and is finally extinguished as the percentage of gas is further increased.

QUES. 544.—How would you use a safety lamp when inspecting for gas, and how could you tell whether or not gas was present?

B.—Pa. (B)

ANS.—The lamp should be held in an upright position and raised cautiously toward the roof at any point where gas is suspected, the flame being carefully observed while the lamp is being raised, to discover the first signs of the formation of a cap above the flame. There are two general methods of testing for gas with the safety lamp, in one of which the flame of the lamp is first lowered to a small, uniform size, $\frac{1}{8}$ inch in height; while in the other method a normal flame is used. In both of these methods, the percentage of gas is determined, according to the experience of the examiner, by the height and action of the flame. When no gas is present, no cap is formed and the flame maintains its normal size. When using the reduced flame in testing for gas, a non-luminous, pale-blue cap may be seen surmounting the flame of the lamp when gas is present in the air. It is caused by the burning of the gas as it comes in contact with the flame of the lamp; the flame also increases in height. When the normal flame is used for testing, the height of the flame indicates the percentage of gas present; but when 6 per cent. of gas is present, the flame of the lamp becomes a waving, spindle-shaped flame that rotates around the central axis of the lamp. When the percentage of gas approaches the explosive limit, there is a cracking sound and slight explosions occur within the gauze; beyond this point, the lamp fills with flame. At such times, great presence of mind is required on the part of the examiner or fire-boss to avoid making any quick movement, which will cause the flame of the burning gas to pass through the gauze.

QUES. 545.—What indication does a safety lamp give of the presence of gas, when a small amount only is present?

B.—Ind.

Ans.—The first indication of the presence of gas, given by a safety lamp, is a slight increase in the height of the flame and a barely visible flame cap that surmounts the luminous flame of the lamp. This occurs when there is about 3 per cent. of gas present. An experienced observer, under favorable conditions, can detect gas as low as 2.5 per cent. by the appearance of the flame of the lamp.

Ques. 546.—How would you approach a place with a safety lamp, where you expected to find gas, and if there, how would the gas act in your lamp, and what would you do immediately on discovering it? *F_2.—Ala.*

Ans.—A place where gas is liable to be found must be approached with caution, the flame of the lamp being carefully observed from time to time, and the lamp raised cautiously toward the roof to test for gas. If there is sufficient gas present, it will be manifested by a small pale-blue cap surmounting the flame of the lamp. When the amount of gas present is 3 per cent., or greater, the flame cap can be observed in almost any safety lamp; as the percentage of gas increases, the flame cap grows in height and when the proportion of gas amounts to 6 per cent. (depending on the purity of the gas), the flame of the lamp assumes a wavy, spindle shape, and crackles or snaps; beyond this, slight explosions occur within the lamp. As the percentage of gas still further increases, the lamp fills with flame. This is called flaming, and when it occurs great presence of mind is required on the part of the man holding the lamp, as a quick movement of the lamp may readily precipitate an explosion, since the flame will be driven though the gauze and ignite the gas on the outside of the lamp. The lamp should be carefully withdrawn from the gas, as soon as the flame cap and its height have been observed.

Ques. 547.—What indications are given by the lamp when gas is present as an explosive mixture? *B.—Ind.*

Ans.—When the amount of gas present in the air assumes explosive proportions, the effect on the flame is to render it voluminous; that is to say, the flame increases in volume, assumes a spindle shape, jumps, and crackles when the gas is sharp or pure and slight explosions then occur within the lamp, which increase in rapidity and violence with the quantity of gas present. When the condition of the gas is more uniform or diffusion is complete, the entire gauze fills with a pale-blue flame. When the normal flame is used in testing, the flame rotates about the central axis of the lamp in a weird manner just before the lamp fills with flame.

Ques. 548.—How should a safety lamp be used to detect the presence of firedamp? How should it be used in an inflammable current having a velocity of 360 feet per minute? *F.—Pa. (A)*

Ans.—When testing for gas, the safety lamp should be held in an erect position and raised slowly toward the roof, where an accumulation of gas

is suspected. The flame of the lamp, when testing for gas, is sometimes reduced to a mere glimmer, at other times the normal working flame is used; in either case, the light of the flame is screened from the eye of the observer by placing the left hand over the gauze of the lamp. To obtain the best results, the test should be made in as quiet a place as possible, and the lamp screened from the air-current, which interferes with the formation of the flame cap. The observed height of the flame cap makes known, approximately, the percentage of gas present in the air. With a velocity of 360 ft. per min. (6 ft. per sec.), the Davy lamp should be carefully screened from the force of the air-current; a shield extending two-thirds around the lamp, or a glass cylinder completely surrounding the gauze being used, as in the Geordie lamp. To obtain the best results, without withdrawing from the air-current, the test should be made in as protected a place as possible.

QUES. 549.—A lighted safety lamp is placed in contact with a body of firedamp in such a position that the gas continues to burn within the gauze. Give the time, in your opinion, that may elapse before an explosion will take place. *F.—Pa. (A)*

ANS.—This will depend on the perfectness of the gauze and its condition; a dusty or dirty gauze, or an imperfect gauze, will pass the flame in a shorter time than a gauze in good condition. It would be very unsafe to depend on any gauze as affording protection for any specified length of time. When a lamp flames, it should be quietly but promptly removed from the gas. An unbonneted Davy has been permitted to flame for 4 or 5 min. at a time while the gauze remained dark, and no damage resulted; also, the same lamp has been moved toward a feeder of gas, the lamp flaming at a distance of 3 ft. from the feeder, slight explosions occurring at a nearer approach, and the flame being depressed and almost extinguished at a distance of 1 ft. from the feeder, when the lamp was quietly removed from the gas without passing the flame; this was done with a normal working flame. The gauze of a safety lamp, however, after a brief period, often becomes covered to a dangerous extent with the dust floating in the mine air; and when placed in this condition in a body of gas may suddenly and without warning permit the passage of the flame and the firing of the gas outside of the lamp. When in such condition, a slight jar of the lamp will often cause a flash of flame to surround the lamp outside of the gauze, when a small percentage of gas is present in the air, without doing further damage than the burning or scorching of the person holding the lamp; the lamp is then said to flash. From these conditions, it will be observed that it would be very unsafe to set any time limit to the protection afforded by a safety lamp flaming in a body of gas.

PRACTICAL OPERATIONS

QUES. 550.—If, suddenly, you found yourself in an explosive mixture of air and gas, state briefly what you would do. *B.—Pa. (B)*

ANS.—The presence of an explosive mixture of air and gas would be made known by the lamp filling with flame. In such a case, the lamp should be promptly though cautiously lowered, and carefully smothered under the coat or other garment, while the person withdraws as quickly as possible to fresh air. The precaution must be taken to carefully shield the lamp from the force of the current due to its quick removal.

QUES. 551.—How should a safety lamp be treated when found to be full of flame, as the result of being in an explosive mixture? *B.—Pa. (B)*

ANS.—The lamp should be at once carefully removed from the gaseous mixture. No quick movement should be made, as this might cause the flame to be blown through the gauze by the wind due to the quick motion. The lamp should then be covered with a coat or smothered unless the flaming ceases immediately, which it will do on reaching pure air. Great care is required to prevent accident, and much presence of mind is needful on the part of a fire-boss in case of flaming in his lamp.

QUES. 552.—How would you proceed to enter a place that was supposed to contain firedamp, and where would you hold the safety lamp in order to find it? F_1.—*Ala.*

ANS.—The place should be entered cautiously, making frequent tests by raising the safety lamp toward the roof to ascertain the quantity of gas present and to avoid walking unconsciously under and into a large body of gas. All movements of the body should be slow to avoid disturbing any accumulated body of gas

In testing for gas the lamp should be held in an erect position at the roof or at the highest point where gas may accumulate.

CONDITIONS REQUIRING USE OF SAFETY LAMPS

QUES. 553.—Describe the conditions requiring that a mine be worked by locked safety lamps, and what provisions should be made to have extinguished lamps relighted. *F.—Pa. (A)*

ANS.—Locked safety lamps should be employed in any mine generating or known to have generated explosive gas in such quantity as to produce a dangerous condition of the mine air. This requirement is not put into practice as stringently as safety would often require. Many mines, though

generating explosive gas only in small quantities, present dangerous conditions demanding the use of locked safety lamps owing to the dusty condition of the mine and the inflammable nature of the coal. Other mines having a less inflammable coal and less dust may generate larger quantities of explosive gas and may still be safely worked with open lights. Some mines newly developed generate much gas and require the use of safety lamps for a time, after which the quantity of gas given off at the face decreases and the use of locked safety lamps is then abandoned, Still other mines in the immediate neighborhood of gaseous workings give off but little gas, and seem not to require the continuous use of safety lamps. All of these mines present conditions that are or may become dangerous, and require a constant and careful watch of the gaseous condition of the air to avoid accidents. The use of locked safety lamps in any case does not guarantee absolute security against explosion. The safety lamp is, to an extent, a hindrance to the work of the miner, who is prone to expose himself to considerable risk and often prefers to use a naked light, except where the conditions are manifestly present demanding the use of safety lamps only. Under ordinarily favorable conditions, locked safety lamps should be used when the gas exceeds 2 per cent. in a bituminous or 2.5 per cent. in an anthracite mine; but a dry, inflammable coal should not be worked with open lights when more than $\frac{3}{4}$ per cent. of gas is present at the face, owing to imminent danger of explosion under these conditions.

The Anthracite Mine Law of Pennsylvania (Art. 12, Rule 9) requires the use of locked safety lamps when approaching abandoned workings where dangerous accumulations of gas are liable to occur. The law reads as follows:

> In every working approaching any place where there is likely to be an accumulation of explosive gases, or in any working in which danger is imminent from explosive gases, no light or fire other than a locked safety lamp shall be allowed or used.

A lamp station should be located on the intake airway at a point as far inby as practicable, and free from any danger from explosive gases. This lamp station should be in charge of a duly authorized person who should examine and relight any lamp brought to him for that purpose. Where such a lamp station is not maintained in the mine, all lamps extinguished by accident should be sent to the surface for relighting.

QUES. 554.—When, where, and under what conditions should safety lamps be used in order to secure safety to the workmen? *B.—Pa. (B)*

ANS.—The Bituminous Mine Law requires that locked safety lamps shall be used in all portions of a mine where explosive gas is generated, or to which it may be carried in such quantities as can be detected by the ordinary safety lamp, and also in pillar and other workings where a sudden inflow of gas is likely to occur. The law requires that no safety lamp shall be entrusted to any person for use in a mine until he has given satisfactory evidence to the mine foreman that he understands its proper use and the danger of tampering with the same. The law also requires that the

fireboss, in making his customary examination of the working places of the mine, shall use no other light than that of the safety lamp. Such examination is required in all mines wherein explosive gas has been generated within a period of 6 mo. preceding.

QUES. 555.—What is the Illinois Mine Law in reference to safety lamps and their care? *F.—Ill.*

ANS.—The Illinois Mine Law (Sec. 29) reads as follows:

(*a*) *Operator Must Furnish.*—At any mine where the inspector shall find that firedamp is being generated so as to require the use of a safety lamp in any part thereof, the operator of such mine, upon receiving notice from the inspector that one or more such lamps are necessary to the safety of the men in such mine, shall at once procure and keep for use such number of safety lamps as may be necessary.

(*b*) *Mine Manager Must Care For.*—All safety lamps used for examining mines or for working therein shall be the property of the operator, and shall remain in the custody of the mine manager, or other competent person, who shall clean, fill, trim, examine, and deliver the same, locked and in a safe condition, to the men, upon their request, when entering the mine, and shall receive the same from the men at the end of their shift. But miners shall be responsible for the condition and proper use of safety lamps when in their possession.

QUES. 556.—Wherever explosive gas is known to exist and safety lamps are used, what are the precautions mentioned in the Special Rules of the Coal Mines Regulation Act, British Columbia? *M.—B. C., Canada*

ANS.—Rules 75 and 76 of the Special Rules read as follows:

75. Wherever explosive gas is known to exist, and safety lamps are used, no person shall be allowed to smoke tobacco in such part of the mine, or to have in his possession any lucifer match or other material intended for lighting tobacco.

76. Wherever safety lamps are required or directed to be used, no person shall use any open lamp.

CHAPTER V

INSPECTION AND REGULATION OF GASEOUS MINES

EXAMINATION OF MINE WORKINGS FOR GAS

QUES. 600.—What would determine whether or not any particular part of a mine should be examined for gas? *B.—Ind.*

ANS.—Where explosive gas is present in a seam or in the overlying or underlying strata, all the working places, airways, and mine passages should be examined regularly, at stated intervals, to ascertain whether any gas is being given off in dangerous quantity, and to discover any new falls of roof or coal that might liberate fresh quantities of gas. No part of a gaseous mine should be allowed to go without a careful and regular examination. Where gas has not been previously detected in a seam, a daily examination for gas is not so important, but if gas is detected at any time in any of such workings, the fact should be reported at once to the mine foreman, and the mine foreman or fire-boss should, at stated intervals, make an examination of the mine for the presence of gas. All headings or chambers, whether in gaseous seams or otherwise, when approaching abandoned workings, should be examined regularly, from time to time, to ascertain any increase whatever in gas or water at the working face.

QUES. 601.—How would you conduct your examination of a gaseous mine to ascertain its true condition? *B.—Pa. (B)*

ANS.—A fire-boss should first be thoroughly acquainted with the mine workings. Having carefully examined and adjusted his safety lamp at the surface, and having ascertained that the ventilating apparatus is working properly, he descends the shaft or slope and begins his examination of the mine at the foot of the downcast or at the mouth of the intake airway. The first step is to ascertain that the proper quantity of air is traveling on the main intake. Having done this, the examination proceeds with the air. Falls of roof and cavities in the roof or sides of the passageways should receive special attention. Entering the first room working on the entry, an examination is made for gas at or near the face of the room, and passing through the break-through following the course of the current, the other rooms are examined in the order of their succession, carefully noting any increase in the amount of gas present in the air. Where gas is found in

quantity to be dangerous, either as an accumulation of gas in the roof or at the face of a rise heading, or issuing from the floor or roof due to a fresh feeder being struck or to a subsidence of the roof or a squeeze, the proper danger signal must be placed at the mouth of the affected rooms or chambers. Where no gas is found, the fire-boss marks the date of the examination on the working face as required by law, and as an evidence that he has performed his work at that point.

QUES. 602.—On entering the mine in the morning, what would be your first duty? *B.—Pa. (B)*

ANS.—On entering the mine, the fire-boss should first go the main intake to ascertain that the usual quantity of air is passing into the mine.

QUES. 603.—Suppose you were about to examine the mine for explosive gas, what would you consider your first duty as a fire-boss before you entered on your rounds through the mine? *B.—B. C., Canada*

ANS.—(1) Examine the safety lamp to be used, to ascertain that it is in good working condition, the gauze clean, the vessel full of oil, and the wick well trimmed. (2) Examine the ventilator before entering the mine to ascertain that the machinery is working properly. (3) Upon entering the mine, notice that the usual quantity of air is passing in the main intake; then proceed to examine the workings of the mine in order, following the intake current.

QUES. 604.—How would you proceed to examine a working place to ascertain whether or not it was free from explosive gas, or other dangers? *B.—Pa. (B)*

ANS.—A working place should be examined for gas by slowly raising a safety lamp into all cavities where gas would probably be found. When using a Davy lamp, the flame is first lowered and then carefully watched while the lamp is being raised, to detect the first appearance of a flame cap. The working places should also be carefully examined with respect to the timbering of the roof and the spragging of the coal at the face. The roof should be sounded repeatedly to insure its safe condition, and all loose pieces should be taken down at once. In very gaseous seams, the examination for gas should be made at regular intervals, and especially after any fall of roof or coal, also before firing.

QUES. 605.—If you had charge of a gaseous mine, what observations should you make in visiting the workmen's places, and what would be requisite to comply with the mining law? State fully. *B.—Pa. (B)*

ANS.—Each working place must be carefully examined to ascertain the presence of any gas and the safety of the roof, and the need of timbering.

If gas or other danger is discovered that cannot be quickly removed, it is necessary to fence off the working place or put up a proper danger signal so as to warn any person against entering such place. All such dangerous places must be reported at once to the mine foreman after each examination, and recorded in the book kept at the mine for that purpose, immediately after the examination has been made, such record to be signed by the fire-boss making the examination. The record must state clearly what dangers have been observed and where they exist.

QUES. 606.—After your examination of a mine, what evidence would there be to show you had examined all the working places therein? How and where would you place your danger signals if danger exists? *B.—Pa.* (*B*)

ANS.—The Bituminous Mine Law (Art. 5, Sec. 2) requires that the fire-boss leave some evidence of his presence at the face and side of every place examined; he usually marks the date with chalk on the roof or face of the coal. Art. 20, Rule 7, requires the mine foreman to see that all dangerous places are properly fenced off, and danger signal boards so hung on such fencing that they may be plainly seen.

QUES. 607.—When and where must danger signals be placed in a gaseous mine to comply with the Bituminous Mine Law? *B.—Pa.* (*B*)

ANS.—The law (Art. 5, Sec. 4) requires danger signals to be placed and kept at the mine entrance or in the main intake airway near the entrance of all gaseous mines; and likewise at the entrance or entrances of all mines where operations are temporarily suspended, or where the ordinary circulation of the mine is temporarily stopped. Sections 1 and 2 of the same law require the fire-boss to place a danger signal at the entrance or entrances of all abandoned places of the mine, where firedamp is likely to accumulate. Art. 20, Rule 7, requires that danger signals shall be placed at all dangerous places that are fenced off. These danger signals must always be put up promptly upon the discovery of the danger, and maintained until the danger has been removed.

QUES. 608.—In making an examination of a mine that occasionally produces firedamp, where would it be necessary to use the greatest caution? *E.—Ill.*

ANS.—In this case, caution should always be used when entering the main return airway of the mine, and at the working face, and in pillar workings or when entering any of the abandoned rooms of the mine. Such a mine is really more dangerous and liable to accident than a mine known to be gaseous, where extra precautions are used, and strict regulations enforced relative to the use of safety lamps. Wherever gas is liable to be met at times only, the miners and workmen are prone to become careless and do not exercise the necessary precaution to avoid accident.

QUES. 609.—If certain working places generated gas frequently, and other working places gave off little gas, which would you examine first when making your rounds in the morning, and for what reason? *B.—Pa.* (*B*)

ANS.—Provided that the location of those places giving off less gas is such that it would be practicable to examine them first, this should be done, and the places giving off larger quantities of gas should be left until the last. The reason for this is that the places last named are the most dangerous, and by deferring their examination the condition of those places will be better known at the time when the men commence work, than if they are examined first.

QUES. 610.—If you had charge of a gaseous mine, what observations should you make in visiting the working places, and what should be the form of your report in the record book with reference to dangers observed, supplies needed, etc.? *F.—Pa.* (*B*)

ANS.—The mine foreman should see that each working place is properly ventilated and securely timbered. He should observe the manner in which each miner undercuts and sprags his coal, handles his safety lamp and powder, and blasts the coal. He should see that cars are promptly and properly loaded, and that the necessary supplies of timber and tracking are at hand when needed. He should also make a test for gas wherever there is liability of its being found. The report in the record book should describe the present condition of the mine, giving nature and location of all dangers, and stating any lack of the proper supply of material on hand, or any failure to comply with the requirements of the law.

QUES. 611.—In making the weekly examination of old workings where gas has been discovered, what observations should be made to guard against accidents? How should the report be made? *F.—Pa.* (*A*)

ANS.—Ascertain whether the return airways are open and unobstructed so as to permit the escape of gas into the main return of the district. Observe what air is in circulation in the abandoned area and examine the accessible parts of the old workings for gas.

The report should be made in a book kept for that purpose according to Rule 4, of the Anthracite Mine Law, which reads as follows:

All accessible parts of an abandoned portion of a mine in which explosive gases have been found shall be carefully examined by the mine foreman or his assistants at least once a week, and all danger found existing therein shall be immediately removed. A report of said examination shall be recorded in a book kept at the colliery for that purpose and signed by the person making the same.

QUES. 612.—When the fire-boss reports, in the record book, certain dangers that he has discovered during his examination, what then, is your duty as mine foreman? *F.—Pa.* (*B*)

Ans.—The mine foreman must countersign the daily reports of the fire-bosses in the record book. When notified of any danger existing in any portion of the mine, he must at once take steps for its removal, and do all in his power to insure the safety of the men in his charge, and prevent any one from running into the danger by properly fencing off all the entrances to that portion of the mine.

Ques. 613.—Should the fire-boss report danger from gas and bad roof, state fully what steps you would take in order to comply strictly with the law governing the same. *F.—Pa.* (*B*)

Ans.—The Bituminous Mine Law states that the mine foreman shall give prompt attention to the removal of all dangers reported to him by the fire-boss or other person working in the mine; and requires the mine foreman to see that all dangerous places are properly fenced off, and danger-signal boards hung on such fencing in such manner that they may be plainly seen. Steps should then be taken to remove the danger with due regard to the safety of the men, who should first be withdrawn if circumstances require.

Ques. 614.—What conditions, other than the volume of air passing through the fan or furnace, should a mine foreman consider in order to determine when a mine is properly ventilated? Explain fully. *F.—Pa.* (*B*)

Ans.—He should consider whether all the working places in the mine are free from accumulations of firedamp, blackdamp, and other noxious gases, and the velocity of the air-current is sufficient to remove the gases produced by shot firing and any gas set free by possible blowers. If all these conditions are fulfilled, the mine foreman may, with safety, conclude that the mine is well ventilated, irrespective of the volume of air circulating.

Ques. 615.—What safety lamps would you use, and how would you proceed to prepare your safety lamp? How would you proceed to enter a mine for the purpose of examining the mine for the detection of gases? Should you detect large quantities of gas, what would you do? *I.—Pa.* (*B*)

Ans.—The following are some of the more common safety lamps in use: the Davy lamp for testing for gas, the Clanny, Mueseler, Marsaut, Wolf, Evan Thomas, and the Hepplewhite-Gray lamps. A safety lamp should be prepared for use by carefully examining the lamp to see that the gauze is entirely free from dirt and in perfect condition, that the other parts of the lamp are secure and fit well together and that none are wanting, that there is plenty of oil in the oil vessel, and the wick adjusted to give a normal flame.

Before entering the mine, the ventilating apparatus should be examined to ascertain whether it is working properly. The work of examining the

mine should begin at the intake, or the foot of the downcast shaft, and should proceed in regular order with the air-current after ascertaining that the proper quantity of air is passing into the mine.

The quantity of gas being large, the mine foreman should be notified and all the men in the mine withdrawn at once. After the men are all out of the mine, steps should be taken to remove the gas by gradually increasing the quantity of air in the affected district, having first taken the the precaution to station reliable men at each point of access to such district. The work of removing a large body of firedamp is dangerous, and requires the utmost caution. Only experienced and faithful men should be entrusted with this work. The doors should be arranged so that the gas will pass out of the mine by the shortest practicable route. It may be necessary to erect temporary brattices to throw the air more strongly against the accumulated body of gas. This should be done cautiously, only safety lamps should be used, and these should be kept at a safe distance back from the head of the brattice. The brattice is extended in sections, giving time for the air-current to act on the gas after erecting each section. Great danger would be incurred by attempting to remove the gas too rapidly, or faster than the current of air could dilute it.

QUES. 616.—How would you determine the quantity and percentage of gas in the mine air? *I.—Pa.* (*B*)

ANS.—The percentage of gas in the air-current can be determined approximately by observing carefully the height of the flame cap, or by the use of the sight indicator. The exact per cent. can be determined only by taking a sample of the mine air to the surface and then analyzing by a Shaw gas tester or by chemical analyses. To determine the quantity of gas, measure the quantity of air in circulation and multiply the quantity of the circulation by the percentage of gas in the current. Thus the quantity of gas in a current of 100,000 cu. ft. containing 2 per cent. of gas, is

$$100{,}000 \times .02 = 2{,}000 \text{ cu. ft.}$$

INSPECTION OF MINES FOR GASES

QUES. 617.—Explain how you would, as mine inspector, inspect a mine generating explosive gas, to satisfy yourself that it was being worked according to law. *I.—Pa.* (*B*)

ANS.—The mine map should first be examined to see that it complies with the provisions of the mine law. The mine openings and surface equipment should next be carefully examined, including the arrangements for hoisting and the various safety appliances, to see that they comply with the law. The ventilating machinery should next be examined, the volume of air required in the mine ascertained, and the regulations in regard to the use and care of safety lamps. The book for recording the daily examination of the mine should also be examined to see that it is properly kept. In the mine, the volume of air passing should be measured, both in the intake

and return airways, at the mouth of each split, at the inside break-through, and at the break-through near the face of one or more rooms on each heading or entry. It should be ascertained that not more than 65 persons are working on the same air-current, except where permission has been given by the mine inspector to employ a larger number, not to exceed 100 persons, on any one split or current. The total quantity of air circulating in each split must not be less than 150 cu. ft. per min. for each person employed therein, and as much more as the special conditions in any particular case may require. Particular attention should be given to the timbering of the airways, haulage roads, and travelingways, and to ascertain that a sufficient amount of proper timber is supplied to the men, and used in the rooms and working places. The arrangements for the underground haulage should be carefully examined with respect to the safety of the men. The regulations in regard to blasting, and the handling and use of explosives in the mine should also receive careful attention. The inspector should assure himself that the mine is in charge of a properly certified mine foreman. The inspector should prepare a report by filling out a printed form, or blank, stating the condition of the mine and the date of its examination, the cubic feet of air in circulation, where measured, etc., which report he should post at once in the office of the mine, or other conspicuous place.

EXAMINATION OF WORKING PLACE BY MINER

QUES. 618.—What, in your opinion, is a miner's first duty on entering his working place in the morning? Who should have preceded him there according to law? *F.—Pa. (A)*

ANS.—The Anthracite Mine Law requires each miner to examine his working place before commencing work and also after the firing of every blast, to ascertain if the same is in a safe condition.

Before commencing work, he should always look for the mark at the face of the coal left there by the fire-boss, whom the law requires shall precede him, and who should mark the face of each working place as evidence that he has made his examination that morning.

QUES. 619.—What does the Anthracite Mine Law require the miner in charge of a working place to do before commencing work, and before and after firing a blast? *F.—Pa. (A)*

ANS.—General Rule 34 requires a miner, before commencing work and also after the firing of every blast, to examine and ascertain the condition of his place, and prohibits his laborer or assistant from going to the face of such breast or place until the same has been examined and found to be safe by the miner.

QUES. 620.—Is it necessary for miners to examine their working places after firing shots? If so, why? *F.—Pa. (B)*

Ans.—The return of the miner to the working face immediately after the firing of a shot, to see the effect produced, has resulted in the loss of many lives. At times, the miner has mistaken the report of another shot for that of his own, and has returned to the face only to be blown to pieces by the exploding blast. There is always danger from the condition of the roof after the firing of a blast. The miner cannot see the true condition of the roof on account of the smoke that fills the working place. There is, at times, danger of the miner being burned by a slight gas explosion in a poorly ventilated working place when return is made to the working face too quickly after the firing of a blast. For these reasons, every working place should be carefully examined before the miner begins work after the firing of a shot.

PROCEDURE WHEN GAS IS FOUND IN WORKINGS

Ques. 621.—If you detected gas in one or more working places what would you do to secure the safety of the men working in the adjoining places? *B.—Pa. (B)*

Ans.—The detection of gas in any considerable quantity in working places will necessitate the withdrawal of the men working in such places, and the notifying of the men in the adjoining rooms or places as well as all the men working on the return current affected by the gas. The question as to whether it will be necessary to withdraw all the men on the return of the current should be decided by the fire-boss, and will depend on the quantity of gas being generated and the volume of air in circulation. After withdrawing the men, the ventilation in this section of the mine should be increased if possible. If any large accumulation of gas has taken place in a cavity of the roof, or in any unused portion of the workings, all the men should be withdrawn from the mine before the removal of the gas is undertaken. Where necessary in the removal of the gas, brattices should be erected so as to deflect the ventilating current and make it more effective in sweeping the higher portions of the roof and working places. Except in special cases, the work should be conducted on the intake end of the current.

Ques. 622.—Suppose, just before making your regular inspection of the mine, you discovered that a door had accidentally been left open, thus destroying the ventilation of the mine, say how you would proceed to make your inspection.

B.—B. C., Canada

Ans.—It would be necessary to close the door and wait a proper time for the circulation to be restored in the mine workings. As usual, the fireman should proceed only after ascertaining that the proper ventilating current is passing in the intake. If practicable, the circulation of the mine may be increased by increasing the speed of the ventilator. He should

follow the intake current into the mine, examining with more than usual care each place where an accumulation of gas might be expected. After the inspection of the mine, the fact that the door was left open should be noted upon the daily report.

QUES. 623.—In a mine ventilated by two currents or air splits of unequal length, and which generates considerable quantities of firedamp, a regulator is placed in the shorter airway, and stands, when properly adjusted, about half open. One morning on beginning your rounds you find the regulator standing open; what condition would you expect to exist in the mine, and what would you do under the circumstances? *E.—Ill.*

ANS.—Under these conditions, a reduced circulation would be produced in the longer airway, and as a result explosive conditions and accumulations of gas may be expected in the workings. The first thing to do would be to increase, as far as possible, the ventilation in that portion of the mine, by closing the regulator somewhat more than half, and increasing the speed of the fan as much as possible. The shorter split may be examined first, provided that its circulation is still normal. The examination of the workings on the longer air-course should then be commenced, following the air in its natural course. Extra precaution should be taken to see that there is no standing gas in any of the chambers or workings of the mine. It may be necessary to erect, temporarily, extra brattices to circulate the air more completely around the faces of some of the rooms and chambers. Particular attention should be given to the examination of cavities in the roof, and of the higher portions of the workings, and chambers driven to the rise.

QUES. 624.—If there are three sections ventilated by one current, and on visiting the mine you found a blue flame on the safety lamps in the middle section, what would you do for the safety of the miners in the other sections? State whether you can tell beforehand which of the sections would require the most immediate attention. *B.—Pa. (B)*

ANS.—It is fair to assume that the gas is being given off in the middle section; and the men should be ordered to withdraw at once from this section until an examination can be made as to the quantity of the gas and its source. The men in the section immediately adjoining the middle section of the return side should likewise be withdrawn. After the withdrawal of the men from these two sections, the fire-boss should first proceed to examine carefully the section on the other side where the men are still working, to ascertain whether there is any gas in the section. Finding no gas there, the fire-boss should next examine the middle section, following the current in its course through these workings. If anything can be done to increase the volume of air passing in these sections, it should be done

at once, and every precaution taken to prevent explosive conditions of the air-current. In no case should men be allowed to return to the middle section or the section on the return side of this, until a safe condition of the air is secured.

Ques. 625.—If in making your examination you discover a place with 10 inches depth of gas at the face, and tailing back along the roof 20 feet, to a point, what would be your duty in such a case? *B.—Pa.* (*B*)

Ans.—Fence off the place and put up a danger signal warning every one not to enter the place. Precautions should be taken in the adjoining places, where the air should be carefully watched; special care should be taken in the places inby of the one where the gas is located, and, if necessary, the workmen should be withdrawn from these places until the gas is removed.

Ques. 626.—If, in making your examination, you found in one of the headings near the mouth of the same, that a portion of the roof was in a dangerous condition and giving signs of falling, what would be your action in reference to the same? *B.—Pa.* (*B*)

Ans.—Fence off the mouth of the heading at once, and put up a plain danger signal on the fence, that no one may enter the place unwarned. The danger should be reported at once to the mine foreman and entered on the record book, and steps taken to remove the danger and make the place safe.

Ques. 627.—There is a pair of entries in a mine that usually gives off explosive gas. At the time of examining the mine you failed to detect any gas here, but on your return you discovered that one of the stoppings, near the mouth of the entries, had been destroyed; what would be your method of procedure? *B.—Pa.* (*B*)

Ans.—The cause of the destruction of the stopping is a matter demanding a careful investigation on the part of the fire-boss, who should use a safety lamp only, for this purpose. Assuming that the return air passes at once into the main return airway of the mine, these entries alone will be affected. Before restoring the circulation by rebuilding the stopping, the mouths of the entries should be fenced off, danger signals put up, the mine foreman notified, and the danger entered on the record book. The proper steps should then be taken to restore the circulation in the entries by rebuilding the stopping, having first taken all necessary precautions to guard the return current against the entrance of persons therein unwarned.

Ques. 628.—If, in making your examination of a mine you find gas on the falls, what would be your method of procedure and what would you recommend for safety, the mine being operated by naked lights? *B.—Pa.* (*B*)

Ans.—Fence off all entrances to such place, and allow no one to enter the return current; report the danger at once to the mine foreman; and enter the same on the record book. Steps should be at once taken for the removal of the gas, which may necessitate the exclusion of the men from that portion of the mine. In any event, the men should not be allowed to enter the affected district. No naked lights should be used when removing the gas.

Ques. 629.—On your examination of a mine generating explosive gas, you find the ventilation in good condition and no places containing any accumulation of gas; but as you are about to admit the workmen you discover that the ventilation has been interrupted by the stopping of the fan or other cause, what would be your method of procedure? *B.—Pa. (B)*

Ans.—Promptly fence off all entrances to the mine and allow no one to enter until the circulation has been restored and the mine again examined in the usual manner.

Ques. 630.—What are the requirements of the Coal Mines Regulation Act (British Columbia) with regard to the working places? *M.—B. C., Canada*

Ans.—The Act requires that every working place shall be examined by a competent person or persons before work is commenced therein. A safety lamp must be used for this purpose in all mines where inflammable gas has been found within the preceding 12 mo. In mines in which inflammable gas has not been found for a period of 12 mo. preceding, the working places must be examined as far as reasonably practicable once every 24 hr., by a competent person or persons appointed for the purpose, and reported to be safe before work is commenced therein. All entrances to places not in actual course of working must be properly fenced across the whole width of such entrance so as to prevent persons entering the same unwarned.

MIXED LIGHTS

Ques. 631.—Are you in favor of mixed lights in mines where explosive gas is being generated? Give reasons in full.

B.—Pa. (B)

Ans.—The Bituminous Mine Law requires that locked safety lamps be used in all parts of a mine where explosive gas is being generated in such quantities that it may be detected by the ordinary safety lamp, and in pillar workings and other places where a sudden inflow of gas is liable to occur by reason of a subsidence of roof or other cause, and in all airways, roadways, or other parts of the mine through which firedamp may be carried by the air-current in dangerous quantities. Open lights cannot be used in any part of a mine where the above conditions exist except only in districts of the mine having a wholly separate circulation, from

the intake split to the point where the return air from such district reaches the main return. Where a district of a mine having such a separate circulation of air is worked by open lights, while another portion of the same mine is worked with locked safety lamps, the strictest regulations should be enforced at all points where a door or passageway leads from the one district to the other; this can hardly be classed, however, as mixed lights. This term relates properly to the use of open lights at certain times or under certain conditions in portions of a mine generally, or often, requiring locked safety lamps. This should not be allowed, since conditions requiring the use of safeties may arise without a moment's warning. It is too common an occurrence to find in the record of an explosion the statement that the safeties were found carefully laid away while the open lamps were found where they had been blown by the force of the explosion.

QUES. 632.—In mines generating explosive gas, where mixed lights are being used, what precautions, if any, would you take to prevent explosions? *B.—Pa.* (*B*)

ANS.—The necessary precautions to be observed in gaseous mines where mixed lights are used are: (1) a careful watch of the quantity and gaseous condition of the return air-current and constant inspection of the working face, pillar workings, falls, and abandoned places to ascertain the gaseous condition of the air in the workings; (2) an efficient ventilating apparatus consisting of duplicate fans and engines, used alternately and kept in constant repair; (3) a careful watch and superintendence of all ventilating machinery, airways, doors, brattices, bridges, and stoppings, to avoid any accidental derangement of the ventilating current; (4) strict regulations in reference to the loading out of fine coal to prevent the accumulation of dust; (5) the adoption of an efficient system of watering or spraying airways and workings of very dusty mines; in such mines, however, mixed lights should not be allowed.

QUES. 633.—State the regulations and requirements in the use of safety lamps and naked lights in mines as provided in the General Rules of The Coal Mines Regulation Act, British Columbia. *M.—B. C., Canada*

ANS.—General Rule 8 requires that no lamp or light other than a locked safety lamp shall be used in any working approaching a place where there is likely to be an accumulation of explosive gas, and that wherever safety lamps are required each lamp shall be examined by a competent person appointed for that purpose, immediately before it is taken into the mine, to ascertain if the lamp is secure and securely locked. And no lamp shall be unlocked by any person without due authority, and no person without such authority shall have in his possession in any part of a mine where safety lamps are required, any key or contrivance for unlocking a safety lamp, or any lamp or apparatus of any kind for striking a light. The rule also prohibits the use of naked lamps on any part of a return current coming from a portion of the mine where safety lamps are required.

Ques. 634.—Would you consider it safe to work with open lights in any portion of a mine generating explosive gas? Explain why. *B.—Pa. (B)*

Ans.—Mines generating explosive gas are not always dangerous in every portion of the workings. Some mines generate explosive gas in dangerous quantities only in certain sections; for this reason open lights may be used in such mines. There is usually, in such mines, a lamp station located at some point in the mine beyond which it is prohibited to carry or use any but locked safety lamps. The conditions that would permit of the use of open lights in workings generating gas occur only where the ventilation of the workings is ample and reliable, and the gas is given off regularly and in small quantities. Even then it cannot be said that the use of open lights is unattended with danger, since at any time a heavy feeder of gas may be opened by a blast or fall of roof, which would render the workings in the vicinity extremely dangerous in a very short space of time, and it is not always possible to give the warning quick enough to those using open lights to avoid an explosion. For this reason, if absolute safety is to be secured, open lights should always be prohibited in the workings of a mine generating gas in any quantity; but on account of the annoyance and hindrance to the workmen, the use of open lights is permitted until such time as the conditions become dangerous. The men themselves prefer to run the risk of explosion rather than to be compelled to work with locked safety lamps under these conditions, and a careful and constant watch is kept of the gaseous condition of the mine air.

Ques. 635.—In a mine that is being worked with open lights, describe what conditions might be encountered that would necessitate the use of safety lamps. *B.—Pa. (B)*

Ans.—(1) A sudden fall or subsidence of roof; (2) a condition of squeeze or creep; (3) the drawing of pillars; (4) the opening of a fresh feeder of gas; (5) an increased quantity of gas often found after passing through a fault or when approaching a fault; (6) a sudden fall in the barometer, especially where there is a large abandoned area in the mine.

Ques. 636.—An entry 7 feet high and 8 feet wide is filled with gas 100 feet from the face; what would be the result if you entered this heading with an open light? *B.—Pa. (B)*

Ans.—This body of gas would form an exceedingly explosive mixture at the point where it diffuses into the current circulating in the mine airways. The entry of a naked light into this mixture would result in a serious explosion.

Ques. 637.—What advantage and disadvantage would there be in the general use of portable electric lamps in bituminous mines? *I.—Pa. (B)*

ANS.—Such a lamp would possess the advantage of giving a good light without incurring the same risk of igniting gas. Also, it does not vitiate the air by giving off smoke and the products of combustion. Its chief disadvantage, aside from its weight and bulkiness, is the limited time such a lamp will burn.

QUES. 638.—If an open light is placed in a large body of marsh gas, CH_4, unmixed with air, what would be the result? Give your reasons. *B.—Pa.* (*B*)

ANS.—The light would be extinguished because there is no oxygen mixed with the CH_4 to support combustion. It is dangerous, however, to attempt to introduce a light into a body of gas in the mine, for even if a body of marsh gas occurs unmixed with air, the main body of gas will be surrounded by an explosive firedamp mixture, which would probably flame and cause an explosion.

EXPLOSIONS OF FIREDAMP

QUES. 639.—State your views as to the causes of explosions, and what precautions you would adopt to prevent them. *B.—Pa.* (*B*)

ANS.—Mine explosions are most commonly the result of the ignition of a body of firedamp accumulated in some cavity of the roof, or in abandoned or poorly ventilated places in mine workings. The ignition of the gas may be caused by the flame of an open lamp, or the flame of a blast, or the sparking of electric wires. In rare cases, it has been claimed that the firedamp was ignited by sparks struck from flint rocks. The gas may be ignited by the gauze of a safety lamp being defective or heated to redness, or from the flame of the lamp being blown through the gauze by a strong air-current or the force of a blast. Another class of explosions are those known as dust explosions. A dust explosion may occur when a small percentage of marsh gas is present in the air, the ignition of the dust and the violence of the explosion being then greatly assisted by the presence of the gas. Or a dust explosion may occur when there is no marsh gas present in the air. In this case, the explosion arises generally from a blown-out or windy shot whose energy is expended on the air of the workings instead of breaking down the coal. This may occur when a shot blows its tamping (blown-out shot), or when a shot finds vent through a small crevice, crack, or old drill hole, penetrating close to the charge (squealer), or when a shot seams out through a soft stratum of coal, leaving the balance of the coal in place. In all these cases, the energy of the blast is exerted on the air instead of being consumed in breaking down the coal. As a result, the dust and fine coal in the immediate vicinity of the blast are thrown into the air and there acted on by the flame of the blast, which converts them into carbon monoxide that burns and transmits the flame of

the blast through the workings. The commotion caused by the rush of the expanding gases throws more dust into the air and adds to the explosion and transmission of the flame through the entries.

The precautions necessary to prevent, as far as possible, explosions of firedamp in mines are: (1) A more strict enforcement of the mining law with reference to the examination and ventilation of mines and working places, as well as the abandoned portions of the mines; the handling and use of safety lamps, blasting of coal, handling of explosives, etc. (2) An ample ventilating current divided into several splits, according to the requirements of the mine, and well conducted to the face of the workings, and not traveling at too great a velocity. (3) The use of proper safety lamps where conditions require, and the care of such lamps. (4) The enforcement of proper regulations with respect to the handling of the fine coal and slack, and the manner of shooting the coal at the working face. No accumulations of fine coal or dust should be allowed at the working face. These fines are best loaded out with the coal, especially when there is a tendency for the slack to fire in the gob or waste. Good mine cars must be used, in order that the fine coal and dust shall not be distributed along the haulage roads. The sprinkling of the working face and the roof and floor of working places with a copious supply of water previous to firing, has some advantage, but should not be considered as preventing an explosion in the event of a windy or a blown-out shot. (5) Strict regulations should also be enforced with respect to the location, charging, and firing of holes.

QUES. 640.—What are the principal precautions that may be taken against explosions of gas, and fires in mines? *F.—Pa. (A)*

ANS.—The principal precautions to be taken against the explosion of gas in mines and fires resulting therefrom, are the maintaining of an ample air-current in circulation in the mine, and directing this current to sweep the entire working face; also the thorough ventilation of all abandoned portions of a gaseous mine; and the daily, regular examination of all working places by the fire-boss, to ascertain that the place is free from gas and well ventilated, and that the timbering is sufficient to prevent falls of roof, whereby large quantities of gas are often liberated. A standard mercurial barometer should also be located at the mouth of every gaseous mine, and the variations of the atmosphere carefully observed each hour of the day. Any sudden change in barometric pressure should be reported at once to the mine foreman, and extra precautions taken to prevent a dangerous increase of the percentage of gas in the air-current. Precautions should also be taken against the accidental ignition of gas feeders from the flame of a blast or a naked lamp, which has often given rise to serious fires in mine workings. Gas feeders in the floor sometimes become ignited, and draw back under the gob or waste, and burn for days. Such burning feeders should be extinguished as soon as they are detected. This may often be done by the explosion of a small amount of dynamite in the vicinity of the burning gas, the concussion of the explosion extinguishing the flame.

Mine fires resulting from spontaneous combustion, in the gob and waste places of a mine, should be particularly guarded against, and every means used to extinguish such fires when discovered. This class of gob fires is best prevented by taking the precaution of loading out the fines or coal slack, instead of storing the same in the gob.

Blasting in dusty mines or in gaseous workings should only be allowed after a thorough examination for gas of the working face in the vicinity of a shot. Every shot should also be examined by an authorized person who has the power to condemn and prevent the firing of any shot that, in his opinion, is unsafe. The working face in the vicinity of the blast should always be free from accumulations of gas and fine dust, and where the coal is particularly soft and gaseous the immediate vicinity of the blast should be sprinkled before a shot is fired.

NOTE.—This question is often asked in the following ways, but the answer applies to either form: "In mines producing firedamp, endangering the lives of the men and the company's property, what means would you employ to obtain the greatest degree of safety?" "How may the greatest security be obtained where danger from firedamp exists?"

QUES. 641.—What do you assign as the cause of the greatest number of explosions of firedamp? *F.—Pa.* (*A*)

ANS.—The largest number of explosions of firedamp are probably caused by the use of naked lamps in mines generating any considerable quantity of explosive gas, and the use of mixed lights in mines giving off little gas or generating gas at irregular times. Too much reliance is generally placed on the efficacy of an ample ventilating current moving in the airways, and sufficient care is not taken to safeguard this current. Slight occurrences, such as the setting open of a gate or door, a fall of roof in the workings, the striking of a fresh feeder of gas, or a sudden fall of the barometer, may at any time decrease the ventilating current or increase the quantity of gas, and produce a dangerous gaseous condition of the workings. The open lights of the men at the face give no warning of the change in the gaseous condition and an explosion results. Many times, the gas accumulated during the short interval of time when the air-current was deranged by an open door or otherwise, is carried down and ignited by the open lights at the face when the current is restored. The dust raised by the force of a blast, or at times in the loading of a car, is sufficient to produce an explosive condition of mine air containing as low as 1 per cent. of gas. A loader, while loading a car 5 yards back from the face, was severely burned by the flashing of his lamp hanging from his waist belt, in an English colliery, while the men at the face of the same chamber were not harmed. This is a common accident due to the effect of dust to widen the explosive range of the gas. The inattention given to the danger of small percentages of gas mixed with dust existing in mine air, with no means at hand of indicating its presence and giving proper warning, is probably the cause of a larger number of gas explosions than is generally realized.

QUES. 642.—If a serious gas explosion should occur in a mine where a large air volume is being produced by a fan, what would be the possible cause of such an explosion? *B.—Pa.* (*B*)

ANS.—The air may not be properly distributed in the mine, leaving some sections with an insufficient amount of air for the proper dilution of the gas; or the circulation in any section of the mine may have been temporarily deranged by the setting open of a door or the failure of a brattice. The explosion may be due to the ignition of a body of firedamp that has accumulated at some point where the air-current does not reach; or poor and leaky stoppings may prevent much of the air from reaching the face, and the circulation at this point may be insufficient for the dilution of the gas given off. A fall of roof or coal may have set free a large quantity of gas that was ignited by the open lights of the men, or a blown-out shot; or an accidental explosion of a keg of powder may have started a dust explosion in dry and dusty workings.

QUES. 643.—State, fully, your opinion of the principal cause of explosions in the mines of Iowa, and give in detail any method you would recommend for their prevention. *I.—Ia.*

ANS.—The coal mines of Iowa are particularly free from marsh gas, CH_4, and other explosive gases, except carbon monoxide, CO, formed by the combustion in the mine workings of coal dust suspended in the air, or produced by blasting. A commission appointed in Iowa to investigate the cause of mine explosions in the state, attributed the cause largely to the methods employed in blasting the coal. Two members of the commission recommended as a means of preventing these occurrences, that all shots should be inspected and fired by men specially employed for the purpose, and that this work should be performed only after all miners and other employes had left the mine. See also answer to Ques. 641.

QUES. 644.—What changes take place in the atmosphere of a mine during an explosion of firedamp? *I.—Ill.*

ANS.—The chemical changes taking place in the mine atmosphere are as follows: The oxygen of the air unites with the carbon of the marsh gas to produce carbon dioxide, CO_2, where a plentiful supply of air is present; a portion of the oxygen also combines with the hydrogen of the marsh gas to produce water vapor, H_2O. Where the supply of air is limited, the combustion of the carbon is not complete, and a varying amount of carbon monoxide, CO, is produced, the nitrogen of the air remaining unchanged in both cases. When a considerable proportion of carbon monoxide is produced in the first burning or explosion, there usually results a return wave caused by the burning of this gas to produce carbon dioxide. Where coal dust is present in suspension in the mine air, the carbon (coal dust), rendered incandescent by the flame of the explosion, acts on the carbon dioxide to produce a larger proportion of carbon monoxide than would otherwise result, thus rendering the afterdamp again explosive. The mixture of gases resulting from an explosion form what is termed the afterdamp of the explosion More lives are destroyed by suffocation in the afterdamp than by the force of the explosion itself.

QUES. 645.—How much oxygen will be required for the complete combustion of 100 cubic feet of marsh gas?

M.—B. C., Canada

ANS.—The chemical equation expressing the reaction that takes place in the complete combustion of marsh gas in oxygen is as follows:

$$CH_4+2O_2 = CO_2+2H_2O$$

There are thus two molecules of O (atomic volume 4) consumed in the combustion of one molecule of CH_4 (atomic volume 2), and hence, the volume of oxygen consumed equals twice the volume of marsh gas burned. Therefore, the combustion of 100 cu. ft. of marsh gas will require

$$100 \times 2 = 200 \text{ cu. ft. of oxygen}$$

QUES. 646.—On what does the force of an explosion depend? What do you understand by the initial force of an explosion?

I.—Ia.

ANS.—Practically, the force of an explosion of a body of mine gas depends on the amount of accumulated gas and the character of the explosive mixture, the condition of the mine air with respect to coal dust, and to a large extent also on the character and size of the workings. A comparatively small body of gas expanding in a thin seam will have an increased effect owing to the contracted area of the openings.

The initial force of an explosion is the force developed by the ignition of the gas before the gases formed by the combustion have commenced to expand. This force is determined by the relative volume of the gaseous products of the explosion and the temperature of ignition of the gas.

QUES. 647.—A gaseous mine is divided into three sections, A, B, and C. Section A contains a firedamp mixture consisting of one part of marsh gas and ten parts of air. The firedamp mixture in section B consists of one part of marsh gas mixed with less than ten parts of air; and that in section C, one part of marsh gas mixed with more than ten parts of air. The gas is ignited in section A. Where would you expect to find the most deadly work done, and which is the most dangerous place to explore? *M.—Ill.*

ANS.—The force of the explosion will be most destructive in section A, where the mixture of marsh gas and air is in the proportion 1 : 10; but the most deadly effects of an explosion are generally produced by the afterdamp, and this will be most dangerous in section B, where the proportion of gas to air is greatest. The afterdamp in this section, owing to the limited supply of air, will contain a large quantity of carbon monoxide, CO. This gas is exceedingly dangerous because of its poisonous effects on the human system, $\frac{1}{2}$ per cent. present in the mine air being fatal to life; the lights, however, will continue to burn brightly in a much larger percentage of this gas. Owing to these causes, section B of this mine will be the most dangerous section to explore after the explosion.

QUES. 648.—Is it possible to have an explosion in a mine where the safety lamp gives no indication of firedamp?

M.—B. C., Canada

ANS.—Yes; an explosion may occur (Galloway) in a dusty mine when less than 1 per cent. of marsh gas is present, and the common Davy lamp gives no indication of gas when less than 2 per cent. is present, under the most favorable conditions. The ordinary miner cannot detect less than 3 per cent. of gas in the lamp.

Also, a mine explosion may result from a large quantity of fine coal and dust being thrown into suspension in the mine air by the force of a blast. This fine dust acted on by the flame of the blast distils carbon monoxide, CO, and may result in a serious mine explosion, whether marsh gas is present in the air or not.

QUES. 649.—Why does an explosion of firedamp in a mine render the air therein dangerous to health and life?

B.—Pa. (B)

ANS.—The explosion of a body of firedamp in a mine destroys the available oxygen in the air, and the gases that form the resulting afterdamp do not support life. The afterdamp of an explosion always contains a considerable percentage of carbon monoxide, CO, which is one of the most violently poisonous gases of the mine. The presence of this gas in the afterdamp is usually unsuspected, because it supports combustion and allows the lamp to burn even more brightly than before. It is, therefore, the most dangerous of all mine gases.

QUES. 650.—There are ten chambers driven off a gangway; an explosive mixture is discovered in the fifth of these chambers; what precautions would you take to guard against an explosion?

F.—Pa. (A)

ANS.—The men should be promptly withdrawn from the chamber in which the explosive mixture is discovered and from all the places inby on this current. If the quantity of gas is small and can be readily controlled, the chambers outby on the current may be permitted to continue work while the gas is being removed. If the body of gas is large, however, the men should be withdrawn from all the chambers as a precautionary measure to avoid the possibility of the ignition of the gas. Prompt measures should then be adopted to increase the quantity of air passing through these chambers, if possible, conducting the return from them immediately into the main return airway so that the gas will be carried at once out of the mine and not allowed to pass into other portions of the mine. No one should be permitted to enter the return air-current while the gas is being removed.

NOTE.—The terms inby and outby imply direction; when applied to a mine they signify direction toward the working face and toward the mine opening, respectively. Applied to the air-current they signify direction toward the discharge and toward the intake opening, respectively. Inby on a current means in a direction in which that current is traveling; outby on a current means in a direction against the current.

COAL DUST

QUES. 651.—What is coal dust? State what dangers arise from the same when blasting is carried on where it is present; also, what would you do to prevent a possible accident due to the presence of coal dust? *F_1.—Ala.*

ANS.—Coal dust is coal in a finely powdered condition, the particles of dust often being so fine as to be readily held in suspension by the moving air of the ventilating current.

When fine dust has accumulated at the working face, the force of a blast will often raise this dust, which acted on by the flame of the explosion distils carbon monoxide, which is combustible and extends the flame of the explosion a considerable distance in the workings, often igniting an otherwise isolated body of gas remote from the face.

To prevent such an accident, every precaution should be taken to avoid all accumulations of dust at the working face; and the roof, floor, and coal of the workings should be sprinkled with water previous to firing, in all cases where the coal is particularly inflammable.

QUES. 652.—What quantity of marsh gas in air clouded with coal dust will make the mixture explosive? Can this quantity be detected on the flame of a safety lamp? *B.—B. C., Canada*

ANS.—The presence of coal dust suspended in firedamp widens the explosive range of mixtures of air and marsh gas more or less. The least percentage of marsh gas that will render air clouded with coal dust explosive will depend on the inflammable nature of the coal and the character of the gaseous mixture. The experiments of Abel, Galloway, and others, have proved quite conclusively that a mixture of marsh gas and air containing less than 1 per cent. of marsh gas but containing also a highly inflammable coal dust is explosive; this percentage of gas is much below what can be detected by the flame of an ordinary Davy lamp. The Clowes hydrogen lamp, the Stokes and Pieler alcohol lamps, the Wolf naphtha-benzine lamp, and the Beard-Mackie sight indicator used in a common Davy lamp burning sperm oil, will show the presence of less than 1 per cent. of gas.

QUES. 653.—Will coal dust influence a mine explosion? If so, how? *F.—Ia.*

ANS.—Wherever coal dust in a finely divided state is present in a considerable quantity in mine workings, either at the face or along the mine passageways or haulage roads, it is thrown more or less into suspension in the air of the mine by the velocity of the air-current, the force of a blast, the traveling of men and animals, and the haulage of cars. The influence of any considerable amount of coal dust thus raised and held in suspension in the mine air is: (1) To render explosive any small amount of gas present in the atmosphere and which would not otherwise be explosive. (2) To

lengthen or extend the flame of an explosion of gas in the mine. The flame of an explosion is thus often carried from one point to another point in the mine, and bodies of gas ignited that would have been wholly isolated from each other had it not been for the coal dust held in suspension in the airways connecting them. The ignition of an isolated body of gas is thus often caused by dust held in suspension in the air. Coal dust, when acted on by a considerable body of flame, either of a blast or an explosion of mine gas, is converted into carbon monoxide, which is combustible and propagates or transmits the flame of a blast or explosion. (3) An explosion of mine gas in the presence of fine dust is intensified and rendered more violent than would otherwise be the case. (4) The presence of fine coal dust in the vicinity of a blast may create a gas explosion when thrown into suspension by the force of the blast and converted into gas, as just explained, by the flame of the explosion; the force of the gas explosion that ensues throws more dust into the air, which furnishes the means for the production of more gas, and extends the explosion in the mine. A blown-out or a windy shot occurring under such conditions is almost certain to produce a gas explosion of considerable proportions.

NOTE.—The form in which this question is asked is often varied as follows: "What is the effect of coal dust on an explosion of firedamp?" "When gas is exploded, what effects are caused by coal dust suspended in the air?" "Is coal dust ever an element in an explosion of firedamp? If so, how?"

QUES. 654.—How may coal-dust explosions in mines be prevented? *F.—Ind.*

ANS.—The best means of preventing explosions of coal dust in mines is to avoid its accumulation by loading out the dust and fine coal as made at the working face, and to clean the roadways regularly of all coal and dust accumulating from the haulage of the coal from the face to the shaft bottom. Where the coal is soft and particularly inflammable, precautions should be taken in regard to the firing of shots, the size and number of charges employed, and the method of firing. The holes should be inspected before firing by a competent and authorized person. In gaseous mines, the dangers arising from the presence of coal dust are much greater than in mines free from gas; and under these conditions competent and experienced shot firers should be employed to fire all shots after the men have left the mine. In all cases where the working face is particularly dusty, water should be used to sprinkle and lay the dust in the vicinity of shots, before firing the same; but reliance should not be placed on this as a safe method and as justifying or rendering safe the accumulation of dust and fine coal at the face.

QUES. 655.—How would you overcome the dangers that arise from the presence of coal dust in the bituminous mines of this state? *I.—Pa. (B)*

ANS.—The dangers due to the presence of coal dust in bituminous mines may be greatly reduced by observing the following precautions: Load out the dust and fine coal as made at the working face, and keep the roadways clean of all coal that falls from the cars as they are hauled

to the shaft bottom. Where the coal is soft and inflammable, extra precautions should be observed in blasting the coal not to overcharge the holes; to tamp thoroughly and securely with clay or other non-combustible material; and not to fire any shot depending on the work of a previous shot fired at the same time and expected to explode first. The holes should be inspected before firing by a competent person. In gaseous mines, the dangers arising from the presence of coal dust are greater than in other mines free from gas; and under these conditions, competent and experienced shot firers should be employed to fire all shots after the men have all left the mine. The sprinkling of the face and the roof, floor, and ribs of the workings in the vicinity, before the firing of shots, has been advocated by some; but reliance should not be placed on this means as a preventive of accident.

Ques. 656.—To what extent is coal dust found in the bituminous mines of Pennsylvania? State fully the cause for its existence. *I.—Pa. (B)*

Ans.—Coal dust is present to a very large extent in the bituminous mines of Pennsylvania. It is produced by the grinding and crushing of the coal incident to all the operations of mining, such as the cutting, blasting, and handling of the coal. Where machines are employed the production of dust is much increased.

Ques. 657.—Where, in the bituminous coal regions of Pennsylvania, are explosions from coal dust to be expected; under what conditions in the operation of mines? *I.—Pa. (B)*

Ans.—Explosions of coal dust in the bituminous regions of Pennsylvania may be expected to occur most frequently where the soft coking coals are found and where the seams are exceedingly dry and the coal yields a high percentage of volatile matter, as in the coal mines of the Connellsville district. Coal dust will be found most abundantly in the vicinity of the working face and on the haulage roads where trips are run at a high velocity.

ENTERING A MINE AFTER AN EXPLOSION

Ques. 658.—In case of an explosion in one of the shaft mines of your district, and upon your arrival at the said shaft you found that no one had entered since the explosion, and that many workmen were yet in the mine, state fully each step that you would consider essential to be taken to insure the safety of the rescuers and the rescue of the workmen. *I.—Pa. (B)*

Ans.—First, examine carefully the ventilating machinery and see if the air-current is moving properly. Call for volunteers, and select only those whose judgment can be depended on. Provide each man with a safety lamp. Examine each lamp to see that it is in good condition. Enter the

mine with the fresh air, and never travel ahead of the air. Divide the party into two divisions, one division for exploring the air-courses in advance, the other and larger division for making the necessary repairs to brattices, doors, stoppings, etc. Plenty of boards, brattice cloth, and nails should be at hand. Only such repairs are made as are necessary to maintain the air-current ahead of the exploring parties. The following suggestions are good: (*a*) Talk little and give no advice but what is asked for. (*b*) Keep a watchful eye on the light of your lamp and halt the moment the flame becomes abnormally dull, or bright, or elongated. (*c*) No advance should be made ahead of the air; it is incautious and dangerous. (*d*) Physicians should be in readiness on the surface, and any survivor should be conveyed to the surface at once, as carefully as possible.

QUES. 659.—In the event of a severe explosion in a mine, as mine foreman what would be your first consideration and duty? *F.—Pa.* (*A*)

ANS.—The work of rescuing any possible survivors still in the mine should be prompt and effective. While a hurried call is sent out for volunteers, the ventilating apparatus is examined to ascertain if this has been injured or in any way impaired. If possible, the speed of the fan is increased to provide the largest circulation possible in the mine. A few trusted experienced men are quickly selected, while the necessary materials, such as brattice cloth, boards, nails, and tools, are hurried to the mouth of the shaft. The men selected for the work are divided into two parties and placed in the charge of competent men; the one party proceeds to enter the mine on the intake air and to advance as far into the mine workings as is found safe or practicable, but no one should be allowed to advance ahead of the air; the second party following the first proceeds to repair such brattices, doors, stoppings, etc. as have been broken by the force of the explosion; only such repairs are made as are necessary to carry forward the air required for the work of rescue. In the meantime on the surface, messengers have been dispatched for medical aid, and these, together with ambulances, stretchers, and other accessories are brought to the mouth of the mine. As soon as possible, the victims of the disaster are brought to the surface, or to a place in the mine where they can have pure air and receive medical attention.

QUES. 660.—What are the dangers usually encountered on entering a mine after an explosion, and how would you proceed to overcome them? Explain fully. *F.—Pa.* (*A*)

ANS.—The chief danger lies in the presence, in the mine air, of the afterdamp produced by the explosion. The afterdamp is particularly dangerous when it contains a considerable percentage of carbon monoxide, which permits the light to burn brightly but is extremely poisonous to the human system. The force of the explosion has often destroyed the doors, stoppings, brattices, etc., cutting off the circulation of the air in the mine and preventing any advance being made until these are repaired. The

mine passages are also frequently blocked by falls of roof that render the penetration of the workings exceedingly dangerous. There is generally the danger also of other explosions occurring from the ignition of bodies of gas set free by the falls of roof just mentioned. It is unsafe to explore the mine after an explosion with any but safety lamps properly examined and tested. Each of the rescuing party should be provided with such a lamp; the party should be divided into two divisions; the smaller division to penetrate the entries as far as possible, never going beyond the air, however, to examine the condition of the workings, while the larger division is engaged in making the necessary repairs to restore and increase if possible the circulation of the mine. The entrance of the mine must be made on the intake air, after having examined the ventilating machinery to see that the same is still in working order; only experienced men should be chosen from the volunteers offering themselves for the undertaking. Each body of men entering the mine should be in charge of a thoroughly competent person.

Ques. 661.—In case of an explosion in a mine whereby the doors and air stoppings are destroyed, what method would you adopt to restore circulation? *F.—Ia.*

Ans.—In case of an explosion that has destroyed the doors and air stoppings of a mine, a hurried examination is first made of the fan, to ascertain whether it is still performing its work or has been injured by the force of the explosion, in which case it must be repaired at once if possible, or some other means must be adopted to secure a current of air in the mine. Meanwhile, a call for volunteers having been made, a party of rescuers is organized and equipped with safety lamps and all necessary material and proceeds to enter the mine by the intake opening, as it would be hazardous or impossible to enter the mine in any other way. The rescuers are usually divided into an exploring party and a party whose duty it is to make necessary repairs. The explorers cannot advance farther than they are able to obtain fresh air, owing to the danger of being overcome by the whitedamp, which is almost always present, and in which the lamps of the rescuing party continue to burn brightly. Whitedamp or carbon monoxide, CO, is the most dangerous of the mine gases, because of its poisonous properties and of its presence being not readily detected. The air is carried forwards by temporary brattices and the making of such repairs as are absolutely necessary. Where many stoppings are destroyed or an air-course is destroyed by a fall, a line of brattice is constructed along one side of the entry by stretching brattice cloth upon posts set temporarily, a short distance from one rib of the entry. Any temporary method is resorted to by which the air is carried forwards in the quickest and most direct manner to the working face.

In furnace ventilation, or in cases where the ventilator is destroyed, it may be possible in small openings to secure temporary ventilation in the shaft by pouring water down the downcast shaft, or by lowering a steam jet into the upcast shaft. The upcast shaft should, in such cases,

be protected from the force of the wind at the surface, while the downcast shaft is so arranged as to deflect the surface wind into the intake of the mine. Any or all of these measures should be employed in the attempt to restore ventilation temporarily.

NOTE.—The form for asking this question may be varied as follows: "How should the first examination of a mine, after an explosion of gas, be conducted? What precautions should be taken? State fully." "State what precautions you would adopt in attempting to enter a mine after the explosion of a large body of firedamp." "What dangers are probable after an explosion of firedamp in a mine, and what precautions should be taken when entering the mine?"

MINE FIRES

QUES. 662.—What are the principal causes of fires in coal mines, and what precautions should be taken to guard against them? *F.—Pa. (A)*

ANS.—The principal causes of mine fires are: (1) explosion of a body of gas ignited by a naked lamp, the flame of a blast, a defective safety lamp, sparking of electric or motor wires, or other light, or otherwise; (2) ignition of a gas feeder by the flame of a blast or otherwise; (3) the heating and slow combustion of fine coal in the gob or waste places of the mine; (4) ignition of hay, timber, door frames, or other combustible material by contact with the flame of a lamp or otherwise.

The precautions to be taken to guard against such fires are as follows: A careful and regular examination of the mine before each shift; an examination for gas before firing a blast; ascertain immediately after firing that no feeder of gas has been ignited. Any fine coal produced at the working face should be loaded out instead of being thrown into the gob with the waste from the roof and floor of the seam. The mine workings should be well drained and a plentiful supply of air made to sweep the working face. Good ventilation at the working face is one of the safeguards against gob fires. In non-gaseous mines, it is a good plan to seal the abandoned workings with air-tight stoppings; when this is well done, it is a good preventive against gob fires. Use lanterns or electric lights only in the stables and when handling hay.

QUES. 663.—What, in your opinion, causes gob fires, and what methods would you adopt to decrease the liability to them? *F.—Pa. (B)*

ANS.—The chief cause of gob fires is a gradual heating of the gob, and the spontaneous combustion of the fine coal and slack mixed with the gob. The moist heat of the strata promotes distillation of gas from the fine coal, and this gas permeates the waste and assists in the ignition of the coal. The oxidation of pyrites, when present in the coal, also increases the tendency to fire. To decrease the liability to gob fires, all fine coal and slack should be loaded out from the working face, and the miners not permitted to throw this back in the gob. The tendency to heat and fire is greater in some coals than in others. Also, a free circulation of air and good drainage should

be maintained at the working face. Where the gob has a tendency to fire, the abandoned workings should be well ventilated, or sealed off when no gas is present and given off from the strata.

QUES. 664.—How do mine fires originate, and what precautions are necessary to prevent them? *F.—Pa.* (*B*)

ANS.—Mine fires may originate as the result of carelessness in the use of naked lamps, whereby timber, brattice cloth, powder, hay, or other combustible material becomes ignited; or a gas feeder may be ignited by the flame of a blast; or the fire may be the result of spontaneous combustion taking place in the gob; or the coal or shaft timbers may be ignited by an overcharged furnace. In the first case, more care is required in the use of naked lamps and in the handling of material. In the second case, where the presence of gas feeders is suspected in the coal or adjacent strata, means should be adopted to prevent the flaming of a blast, by the use of either flameless powders or detonating explosives, or by means of the water cartridge often employed for this purpose; or the face should be inspected immediately after firing to ascertain that no feeder has been ignited. When the gob has a tendency to fire, it will be necessary to observe the precautions mentioned in answer to Ques 663.

QUES. 665.—Is spontaneous combustion possible in a coal mine? If so, what are the probable causes producing it, and what means would you employ to prevent it? *F.—Pa.* (*B*)

ANS.—Yes; the probable cause of spontaneous combustion in coal mines is the oxidation of the coal and slack stored in the gob causing a rise in temperature sufficient, finally, for the ignition of the carbon monoxide given off from the coal and penetrating the gob. The process is also promoted by the oxidation of iron pyrites, when present, the sulphur thus set free having a low point of ignition which greatly hastens the result known as spontaneous combustion. It may be partially prevented by not leaving any coal in the gobs and sending all small and refuse coal out of the mine.

QUES. 666.—Are mine fires more likely to occur in one mine than in another; and if so, why? *I.—Pa.* (*B*)

ANS.—Fires are more likely to occur in soft, frail, and in coking coals and in coals that are highly inflammable, owing to the combustible nature of the coal and the large proportion of fine coal produced and that finds its way into the waste of the mine. The presence of considerable iron pyrites also has a tendency, by its disintegration and oxidation, to produce heating and spontaneous combustion of the coal. The method of mining, as tending to produce a greater or lesser quantity of fine coal, and the manner of disposing of the same at the working face, has much to do with the tendency of the coal to fire. The quantity of moisture present and the drainage of the workings, together with the character of the ventilation, also renders some mines more susceptible to fire than others; a moist condition and a sluggish circulation increasing this tendency.

QUES. 667.—When a mine is very dry and dusty, what precautions would you take to prevent fires, and to extinguish any that might occur? *F.—Pa. (A)*

ANS.—In a dry and dusty mine, especially where the coal is inflammable, every precaution should be taken to prevent accumulations of dust or fine coal. An ample ventilating current should be maintained at all times; and in a gaseous mine, the quantity of gas in the air-current should be less than 1 per cent., and safety lamps only should be employed. Where the conditions warrant, water pipes should be laid in the airways with plugs at short distances apart to which hose may be attached. Sections or lengths of hose should be kept ready for use at different points in the airway and at the working face. An abundant supply of water should always be at hand. Water should be used to sprinkle the roof, floor, and coal at the face of the workings before blasting is done, to prevent the fine dust being thrown into the air by the force of the blast. If blasting is performed, the shots should be fired by experienced shot firers. When practicable, a separate traveling way should be maintained in good condition to afford a way of escape.

QUES. 668.—In the event of a mine fire, how would you approach the burning section of the mine; and where workmen are employed in extinguishing the fire, what precaution should be taken to prevent the dangers always to be expected in such cases? *I.—Pa. (B)*

ANS.—A mine fire must generally be approached from its intake side. There is danger of the workmen engaged in extinguishing a mine fire being overcome by the gas produced by the fire, and to avoid this danger a sufficient current of pure air should be conducted to the workmen by temporary bratticing, if necessary, and men should be on hand to rescue such as are overcome or rendered unconscious by the gas. Where explosive gas is present in the mine, the work of extinguishing the fire is extremely hazardous and recourse must be had to smothering the fire by closing the openings of the mine or sealing off a portion of the workings, and filling such mine or portion of the mine with carbon dioxide. If this fails, the fire must be extinguished by flooding the mine. The building of stoppings should begin at the return end and proceed toward the intake. It should be performed quickly to prevent the formation of dangerous quantities of firedamp in the burning section.

QUES. 669.—Describe the dangers attending fires in mines, naming the noxious gases produced. *F.—Pa. (A)*

ANS.—There is danger of the workmen being overcome by the gases produced by the fire; and the final destruction of the mine if the fire is not controlled. If the mine is not destroyed, it may be greatly damaged by the fire or by water in case the fire is extinguished by flooding the mine. In a gaseous mine, there is always danger of the ignition of the gas by the fire.

Where fire occurs in the gob or waste places of a mine and there is not much air, there is produced a large amount of carbon monoxide, which is very poisonous and dangerous, because its presence is often not realized until too late. Where much air is present, volumes of carbon dioxide are produced by the combustion; this gas is not poisonous, but suffocates by excluding oxygen from the lungs. The oxygen of the air is consumed by the combustion of the coal, leaving large amounts of free nitrogen; this gas also suffocates by excluding oxygen from the lungs. If there is sulphur in the coal, sulphur gases SO_2 or SO_3 result from the fire; these are very noxious. In gaseous mines, there is the added danger of the ignition and explosion of bodies of firedamp.

QUES. 670.—In the event of a mine fire, what precautions would you take to protect the workmen in extinguishing the same? *F.—Pa. (B)*

ANS.—The work of extinguishing the fire should be performed on the intake side in order to protect the men as far as possible from the gases of the fire. A practical foreman should be in charge of the work, and the men should be promptly relieved as quickly as they show signs of weakness, or of being otherwise affected by the gas. It may be necessary to perform the work in short shifts, changing the men at frequent intervals. Means should be at hand for resuscitating such of the workmen as may be overcome by the gas, such men being at once carried to a point in the mine where the air is fresh.

QUES. 671.—Name some of the methods used for extinguishing mine fires, also give the methods you have seen, if any, used at collieries where you have worked. *F.—Pa. (A)*

ANS.—A small gob fire slowly smoldering may often be loaded out if taken in time. When this cannot be done, water from a water car may be thrown on the fire, by buckets, or a hose attached to a water-pipe system in the entries may be used, provided that there is sufficient pressure in the pipes. Water, however, should not be used to extinguish a gob fire unless the fire can be surrounded and afterwards cleaned out, as the water increases the tendency of the gob to heat. Hand grenades have been used with good success to extinguish mine fires where timber was burning and water could not be obtained. If delayed and the fire has spread over a considerable area, it may be necessary to isolate the affected workings by building air-tight stoppings or flushing with culm to smother the fire at the entrance to all rooms and passageways in which there is fire. This is done by commencing at the return end of the workings in which the fire is located, and proceeding in regular order toward the intake end; in gaseous workings, this cannot be done owing to the danger of an explosion of gas destroying the stoppings. When timber or other inflammable material has been fired, a prompt and abundant supply of water is necessary to extinguish the same. This work must generally be done from the intake side to avoid the suffocation of the workmen while fighting the fire. Water pipes with taps at short

intervals are frequently laid along the airways. The method of smothering a fire by means of carbon dioxide has frequently been tried with good success. The gas is forced into the rooms or chambers or into that section of the workings where the fire is located after the necessary stoppings have been built to confine the gas. When all other methods of extinguishing a mine fire have failed, the mine may be flooded; sometimes, a single section of the mine only is flooded by building substantial mine dams in the gangways leading thereto. After a sufficient time has elapsed for the extinction of the fire, the water is again pumped out and the workings carefully examined to see that no signs of fire remain.

QUES. 672.—How would you attempt to overcome a mine fire already in operation? *F.—Pa. (B)*

ANS.—When the fire is located in an airway or other passage of the mine, it must be fought from its intake end, since it would be impossible to approach it in any other way. Pipes or hose are quickly laid in the entry so as to conduct water from the pumps to the scene of the fire, and the pump pressure is increased to its maximum. When convenient, steam has sometimes been used successfully to extinguish fires in rooms, the room being first sealed off, and the steam then blown in under pressure from a steam pipe passing through the stopping. Carbon monoxide has also been pumped into a closed space, in the same manner, to extinguish fires in rooms. All efforts to arrest the fire by these means proving unsuccessful, and it being impossible to isolate the fire by building stoppings, recourse must be had to flooding the mine or such portion of it as can be shut off and filled with water. Flooding is always a last resort. If the fire occurs in rooms or chambers, it can generally be isolated by the building of fireproof stoppings at the mouths of these openings, when it will finally smother itself. It is sometimes possible, when the fire is in the return airway, to close tightly the top of the upcast shaft after building a heavy fireproof stopping on the intake side of the fire. When this has been done, steam is introduced into the shaft, and the fire smothered in the products of its own combustion.

QUES. 673.—How would you deal with a gob fire that had attained considerable headway? *I.—Ia.*

ANS.—A gob fire that has attained considerable headway should be carefully and thoroughly sealed to prevent, if possible, the access of fresh air to the fire. The portion of the mine may be sealed by any form of air-tight stopping, but in the anthracite region of Pennsylvania flushing with culm has proved most effective. The work of sealing should begin at the return end and proceed regularly toward the intake in order to avoid the liability of explosion due to the accumulation of an explosive body of gas in the region of the fire. It is not always possible to extinguish a gob fire by sealing alone; carbon dioxide has been pumped into the sealings with good effect. If this fails, recourse is usually had to flooding the mine, or that portion of the workings where the fire is located when this can be accomplished by the building of a mine dam.

QUES. 674.—Suppose that a fire occurred at the inlet to a mine, what would be your first consideration, and how would you try to prevent the smoke from going to the workmen? *F.—Pa.* (*A*)

ANS.—This is one of the few cases that may warrant a reversing of the air-current without notifying the men employed in the works. The only salvation to the men employed inside lies in reversing the air-current in the mine; for, if the air continued on its original course, the smoke and gases from the fire would be carried directly in to the men, and would without doubt suffocate them unless they were able to escape by the return airway in time, which would be extremely doubtful, as many of the men would be busily employed at the face of their rooms or chambers and would not know of the trouble until the airways by which they must escape were filled with smoke and gas.

The first consideration, therefore, in case of a fire at the inlet of a mine, would be to reverse the current, and if the conditions would permit, the fire must be isolated as speedily as possible. It must be attacked from the side of the fresh air, as it can be reached from no other point. Water hose may be used or chemical extinguishers. The latter have been found very effective in many fires. Any attempt to prevent the smoke of the fire from reaching the men by reducing the air-current or deflecting it would only result in reducing the air in the workings and suffocating the men. They must be supplied with fresh air by reversing the current in the manner previously described.

QUES. 675.—If you had a number of men in a certain district and fire was to take place in an intake airway, state how you would proceed to rescue the men. *B.—B. C., Canada*

ANS.—Fire occurring in the intake would result in the suffocation of the men, unless the circulation were promptly reversed or stopped. Set open the main doors at the shaft bottom to short-circuit the air; send word in to the men; open any doors that will carry the smoke into the main return and prevent, as far as possible, its passing into the mine workings. In case it is decided not to reverse the current, steps should be promptly taken to close the top of the downcast shaft or stop off the intake so as to prevent, as far as possible, fresh air from reaching the fire. The method to be adopted will depend on the location of the fire and the arrangement of the entries. Hose or pipes should be laid as quickly as possible to throw water on the fire, which probably can only be done from its intake side. If the fire starts at the foot of the shaft, it may tend to reverse the current by heating the air in the shaft. The conducting of any operations for extinguishing the fire must depend wholly on what is possible to be done further than the essential steps to prevent the entry of the smoke of the fire into the mine workings, and the feeding of fresh air to the fire. In all cases, the fire must be fought from such positions as the conditions afford. Only when the fire passes control should steps be taken to isolate it by the building of dams and the flooding of the mine. Water should be in readiness at the surface, at the

mouth of the shaft, to prevent, if possible, the flames from destroying the shaft. The rescue of the men must be effected through such passageways and openings as the mine affords; this should be prompt, and no effort should be spared to notify all the men in the workings.

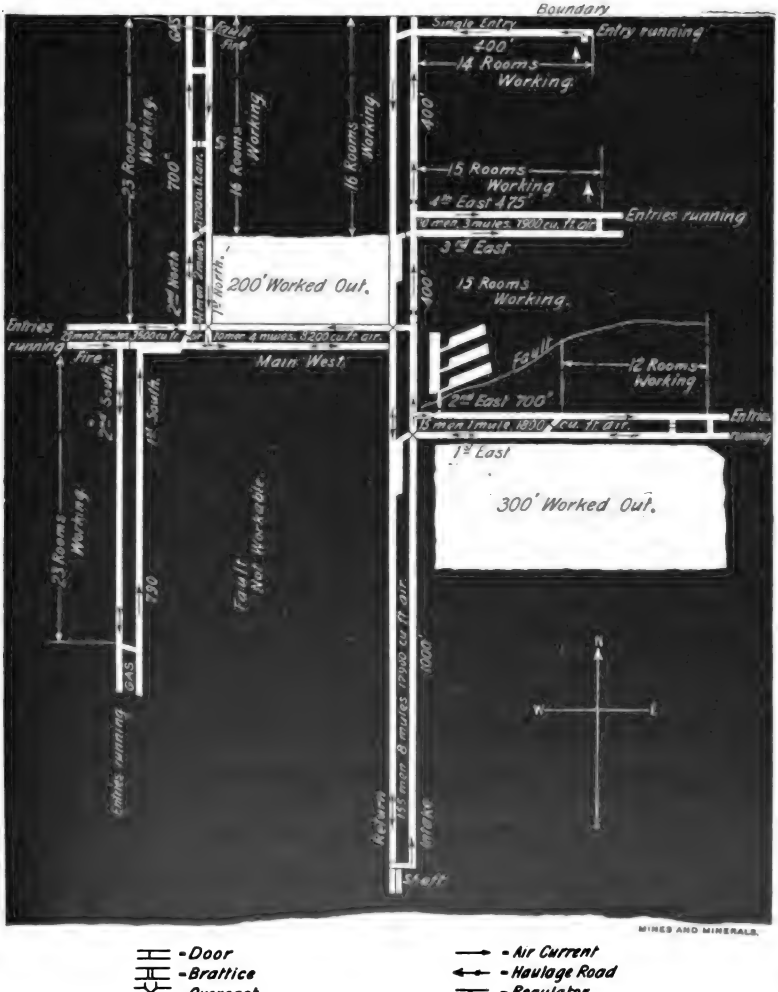


Fig. 1

Ques. 676.—Referring to the accompanying sketch, Fig. 1, we find the coal at the face of the first north, off of the main west entry is on fire. There being no dust or gob accumulations on the entry, what has been the probable cause of the fire? You will also notice

that gas is being driven off at the face of the second north entry, and *S* is the nearest point to the fire, reached by the fire-boss on the morning he discovers it. Explain, in full, how you would direct the work of extinguishing the fire with the least danger to the workmen. *F.—Ind.*

Ans.—It is probable that the gas issuing from the fault at the head of these entries was ignited by a blast fired at the time of quitting work the night before the discovery of the fire. The work of extinguishing the fire should proceed as follows: Assuming that the second north is the intake, and the first north the return of the current in this split, the stopping in the cross-cut at *S* should be first removed, which will cut off much of the circulation at the head of these entries. A temporary stopping should then be quickly erected on the first north, just inside of this cross-cut. When this has been done, a second temporary stopping should be erected in the second north at a corresponding point just inside of the same cross-cut. These stoppings should be tightly sealed in order to cut off the admission of all air to the fire. A long piece of gas pipe should be left in each stopping and closed with a wooden plug. The purpose of these pipes is to ascertain from time to time, the condition of the atmosphere within the stoppings. The pipes should be kept plugged except when ascertaining the condition of the air. The order of erecting and sealing the stoppings is important, since an explosion will almost inevitably occur if the stopping on the intake is erected and sealed before that on the return current. Safety lamps should be used in the performance of this work. The fire-boss or mine foreman should determine, before beginning the work, whether or not it is necessary to withdraw the men working on the return current. If the flow of gas is light, this would scarcely be necessary, especially as fresh air is conducted through the cross-cut at *S*.

Ques. 677.—At the face of the entry *E*, Fig. 2, the coal has

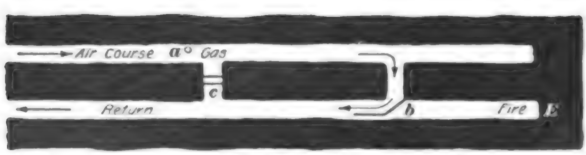


Fig. 2

caught fire from a shot; at the point *a* of the air-course, there is a feeder giving off a large amount of marsh gas; how would you proceed to extinguish the fire and prevent it from spreading? *F.—Ind.*

Ans.—An attempt should first be made to beat out or smother or reduce the fire, using water or steam if available. If the fire is burning well, it would not answer to build a stopping at once, closing off the face of the entry. An effort should also be made to keep the gas coming from the feeder at *a* from reaching the fire at the face of the entry, and for this purpose a temporary brattice *b* might be erected on the return side of the last

breakthrough so as to deflect the gas coming through the breakthrough down the entry; or by making a small opening in the stopping *c* close to the roof, much of the gas from this feeder can be deflected through this hole into the return airway, by a simple brattice at the roof inside of this opening, while fresh air is conducted along the floor under the brattice.

If the fire cannot be put out entirely without sealing it off, as soon as it has been sufficiently reduced, a stopping should be built just inside of the last break-through to seal off the fire, which will smother itself if it has not gained too much headway, and is not drawing fresh air through the pillar separating the two entries. In case it is, it will be necessary to build air-tight stoppings in both entries. If steam is available, steam pipes should be built into the stoppings to assist in extinguishing the fire.

QUES. 678.—How would you proceed to extinguish a fire along the outcrop in a No. 8 seam, separated from that of No. 9 by 3 feet of strata; the thickness of the seams being 7 feet and 5 feet, respectively, and the conditions such as to preclude the possibility of drowning out the fire? *F.—Pa. (A)*

ANS.—The question does not state the method employed in mining the coal in these seams. We may assume, however, that the coal in the upper seam is taken out in advance of that in the lower seam, and that the fire exists in the workings of the upper seam near the outcrop, and has progressed so far that the question of flooding has been considered, but found impracticable or impossible, owing to the conditions, and the only recourse is to isolate and smother the fire. This also may prove a practical impossibility, owing to the proximity of the fire to the outcrop or surface. If stoppings can be built so as to isolate the fire from the other portions of the mine, this should be done at once, and an examination should then be made along the crop line on the surface to discover any evidence of the fire at this point, as manifested by the appearance of smoke or gas, or by the heating of the strata. All should be done at this point that is practicable to prevent air from reaching the fire, but the means adopted to secure this end will be determined in a large measure by the extent and value of the coal to be recovered. As long as a fair chance remains of smothering the fire in this manner, nothing should be done in the mine to break the surface over this portion of the workings. If, however, it develops that air is reaching the fire from the surface, it may be practicable to push forward the mining of the coal in the lower seam and recover what coal is possible before finally closing off and abandoning this portion of the mine.

QUES. 679.—Under what conditions is it safe for men to enter return airways contaminated by gases emanating from a mine fire? *F.—Pa. (A)*

ANS.—It would not be safe under any conditions to enter and remain for any length of time in such an airway unless the quantity of gas coming from the fire was small, or unless they wear some form of rescue apparatus, supplied with compressed air or oxygen. The approach to the fire should be made on the intake side and not on the return.

CHAPTER VI

EXPLOSIVES AND BLASTING

EXPLOSIVES

QUES. 700.—What is an explosive?

ANS.—An explosive is a single substance or a mixture of substances that, by the application of heat or shock, or heat and shock, can be transformed more or less completely into a large volume of gaseous products.

QUES. 701.—Mention the several explosives commonly used in mines; describe their properties and peculiar characteristics; show their adaptation for certain results in blasting operations, and explain the danger attending the use of each. *I.—Pa. (A)*

ANS.—The two classes of explosives in common mining use are as follows: (1) deflagrating explosives, as black powder, in grains or pellets or compressed into charges of convenient size; (2) detonating explosives, to which class belong masurite, and all the nitroglycerine compounds, the most common being dynamite, gelignite, gelatine dynamite, carbonite, ardeerite, etc.; those formed from cotton, as guncotton, tonite, potentite, etc.; and that class of explosives having ammonium nitrate as a base, commonly known as the Sprengel or flameless explosives, as roburite, ammonite, bellite, etc. The deflagrating explosives represented by black powder produce a large amount of flame by their explosion. The size of their grain determines the quickness with which they act; the large-grained powders are slower in their action, the combustion requiring more time to penetrate the grains, and hence they are better adapted for use in soft coal; the smaller-grained powders, being quicker and stronger, are used in hard coal and rock. Detonating explosives are used only in the hardest coal and in blowing top and bottom, or blasting boulders, or driving rock tunnels; this class of explosives produces some flame, but is preferable for blasting in gaseous mines on account of the short duration of the flame. They are always exploded by a cap, containing a small amount of fulminate of mercury that is ignited by an electric current passing over a platinum-wire bridge in the cap. The Sprengel explosives are practically flameless, the products of their combustion being incombustible, and are therefore adapted to blasting in gaseous mines. Guncotton, or nitrocotton, is rarely used in mine workings, the products of its combustion being deleterious to the mine air. Tonite and potentite are forms of guncotton to which nitrate of potassium has been added. They are used to some extent

in gaseous mines. The black powders are most dangerous when used in gaseous mines on account of the large amount of flame they produce when exploded. In the use of black powders, the danger from handling arises from sparks dropping from the miners' lamps into the keg; also from defective fuse and squibs used in exploding the blast. It is a dangerous practice to attempt to draw a misshot. In the use of detonating explosives the danger arises from careless handling of the charge or of the caps, or the attempt to thaw dynamite when frozen.

QUES. 702.—What is the composition of black powder? What is the composition of giant powder? *F.—B. C., Canada*

ANS.—The theoretical composition of black powder is, niter, KNO_3, seventy-five parts; sulphur, S, ten parts; charcoal, C, fifteen parts. It is a common practice, however, to increase the amount of carbon and sulphur and decrease the amount of niter used. In the manufacture of cheaper grades of powder, sodium nitrate is substituted for potassium nitrate (niter), but the powder is not so strong, and is more affected by moisture, which is readily absorbed by the sodium nitrate. Giant powder (dynamite) consists of nitroglycerine absorbed by some porous substance called the dope, which may be a silicious infusorial earth, but is generally wood pulp to which sodium nitrate is added. The nitroglycerine is the explosive element, the absorbent serving merely as a carrier and being wholly inert. The grade of dynamite depends on the amount of nitroglycerine absorbed. Thus a 70-per-cent. dynamite contains 70 per cent. nitroglycerine.

PRODUCTS OF AN EXPLOSION OF POWDER

QUES. 703.—What gases are generated when black powder is fired? When giant powder is fired? *B.—B. C., Canada*

ANS.—The gases produced in the explosion of black powder vary according to the conditions attending the explosion, but may be approximately stated as follows: nitrogen, N, 33 volumes; carbon dioxide, CO_2, 51 volumes; carbon monoxide, CO, 10.5 volumes; moisture, H_2O, 3 volumes; hydrogen sulphide, H_2S, 2.5 volumes. The explosion of black powder in a confined space, as in a drill hole, produces a smaller percentage of carbon dioxide and a much higher percentage of carbon monoxide. The latter, however, is largely converted into the former when thrown out on the air, so that no definite volume can be stated of these two products.

The gases produced in an explosion of 1 volume of giant powder (dynamite) may be stated as follows: carbon dioxide, 469 volumes; moisture, 554 volumes; free nitrogen, 158 volumes; nitrous oxide, 78 volumes, making, say, 1,259 volumes resulting from the explosion of a single volume of nitroglycerine. As before, the volumes of gases produced and the gases themselves vary considerably, according to the conditions under which the explosion takes place.

Ques. 704.—How is the vitiation of mine air caused by an excessive use of powder? *F.—Pa. (A)*

Ans.—The gaseous products resulting from the combustion of powder in blasting often contain a large percentage of poisonous and irrespirable gases, such as carbon monoxide, carbon dioxide, besides hydrogen sulphide and sulphurous fumes, SO_2, and nitrogen, N. An unnecessary amount of these gases is produced by the excessive use of powder in blasting and the air is vitiated or rendered unfit for breathing by their presence.

TIGHT SHOTS, WINDY SHOTS, BLOWN-OUT SHOTS

Ques. 705.—What is the danger from the firing of tight shots? *M.—Ill.*

Ans.—By a tight shot is meant a shot that is too deeply laid, or, as the miner says, too much on the solid, to produce the most effective results. The result is that the temperature of the explosion is very high at the moment when the coal gives way, and the escaping gases reaching the air at this high temperature, burst into flame. Much dust is often raised from the floor by the concussion of the blast, and this dust acted on by the flame of the shot at such a high temperature, may cause a windy shot. At other times, the tamping is blown out, producing a blown-out shot, instead of the coal being broken down. In this case, the force of the powder will be expended on the air instead of being converted into mechanical work in the breaking down of the coal; and if much of the powder is thrown out of the hole and explodes in the air, or if much dust is thrown into the air by the force of the blast, a windy shot or a dust explosion may result. If much dust or gas is present in the airways, a serious mine explosion may result; there is always much danger to the men in the vicinity of the shot.

Ques. 706.—What is meant by the term, a dead hole? What is meant by a windy shot? *E.—Ill.*

Ans.—The term dead hole usually refers to a missed shot, or a shot that has missed fire through some defect of the fuse, or from the fuse or squib not reaching the powder. A windy shot is one expending a part or all of its energy on the air instead of breaking down the coal. This may result from an overcharge of powder, or from the shot blowing its tamping, a portion of the unburned powder being thrown out of the hole and exploded in the air; or the force of the blast may throw a considerable quantity of dust and fine coal into the air, causing a small dust explosion, which is the same in effect as a windy shot.

Ques. 707.—What are the causes of blown-out shots, and what are the dangers attending them? *M.—B. C., Canada*

Ans.—Among the numerous causes of blown-out shots may be mentioned the following: (1) The shot is too deeply laid to break down the coal, and the stemming or tamping insufficient to resist the force of the

explosion. The resistance of the stemming should always be greater than that of the coal to be broken down. (2) Too large a diameter of drill hole may cause the stemming to yield by the excessive pressure exerted on it. (3) The use of too quick a powder or a powder of too fine grain often results in blowing the tamping without breaking the coal.

A windy shot, which is sometimes called a blown-out shot, is the result of: (1) The use of too coarse a powder or a mixture of different grades of powder, which may result in the breaking of the coal or the yielding of the stemming or tamping before all the powder is consumed, whereby a greater or less proportion of the energy of the blast is exerted on the mine air instead of being consumed in breaking down the coal. (2) The energy of the blast finding vent through some fissure or crevice connecting with the hole (squealer). (3) The seaming out of the coal, by which is meant the blowing out of some of the softer strata of the coal seam without breaking down the main body of the coal. (4) A succession of two or more blasts fired in a limited working place often produces the same effect as a windy shot. The danger arising from a blown-out or a windy shot is greater in a dusty mine, or where fine coal has been allowed to accumulate at the working face. The force of the blast expended on the air blows this dust and fine coal into suspension in the air, and this, acted on by the flame of the blast, distils a large quantity of carbon monoxide, which propagates the flame of the blast. In a dry and dusty mine, such an occurrence may result in a serious and widespread explosion of dust and gas.

QUES. 708.—What are the effects of windy or blown-out shots? What precautions should a mine boss take to prevent them?

F.—Ind.

ANS.—The immediate effect of a windy or blown-out shot is dependent on the condition of the working face and the character of the coal. Where the coal is soft and inflammable, or the working face is not kept clean and free from accumulations of fine coal and dust, or where there is gas present in sufficient quantity, the effects are liable to be disastrous, and may result in an explosion of mine gases extending over a considerable area of the mine workings. These effects are often increased by the explosion of powder in kegs left exposed in the working places or in the airways. Fine dust, when present, is blown into the air by the force of a blown-out shot, and being acted on by the flame of the blast distils a large amount of carbon monoxide which propagates the flame and extends the explosion through the mine workings. The extent of such an explosion will depend wholly on the condition of the workings, with respect to the accumulation of dust and fine coal, the quantity of air in circulation, and to some extent on the quantity of carbon dioxide or blackdamp present. Carbon dioxide, in presence of the incandescent carbon, in a mine explosion, is converted into carbon monoxide or whitedamp, which transmits and adds to the force of the explosion. Under certain conditions, however, the quantity of blackdamp may be such as to extinguish the flame of the explosion and render the firedamp inexplosive.

The most effective precautions to be taken to avoid these occurrences are a systematic and thorough inspection of all shots by a competent and authorized person, previous to the firing of the same. Strict regulations should be enforced in regard to the storage of powder in the mines and working places, the amount and number of charges used in different holes, the drilling and stemming of holes, etc. All working places should be kept clean, and the fine coal and slack loaded out, especially where the coal is highly inflammable. In gaseous mines, or where the conditions are urgent, all shots should be fired by competent and experienced shot firers after the men have gone from the mine.

HANDLING DYNAMITE

QUES. 709.—Explain the proper method of thawing dynamite cartridges. *F.—Pa. (A)*

ANS.—Either of the following methods may be used:

(*a*) A few sticks of the dynamite to be thawed are carefully placed in a vessel; and this vessel is placed within another vessel holding water that has been heated to a temperature of about 140° F. The water is kept at this temperature by a coil of steam pipes surrounding the outer kettle.

(*b*) When a larger amount of dynamite is to be thawed, a small house should be used for the purpose. The dynamite is placed on shelves around the room, which is heated by steam pipes, and some steam is preferably allowed to escape from the pipes into the air of the room, to insure no overheating of the explosive. The house is banked with earth, or, preferably, with fresh manure; and sometimes fresh manure is spread on the floor of the room. A sufficient quantity of dynamite for 1 day's use is placed on the shelves and allowed to remain there for at least 2 or 3 days.

QUES. 710.—Is it necessary to tamp holes charged with dynamite; and, if so, how would you do this with the greatest degree of safety, and so as to obtain the best results? *F.—Pa. (A)*

ANS.—It is not absolutely necessary to tamp holes charged with dynamite. Better results may, in some instances, be obtained by tamping, but the action of the dynamite is so violent and sudden that the tamping is generally of little importance. In vertical holes, water is sometimes used for tamping; the best manner of tamping dynamite is to insert a small plug of clay after pressing the cartridge home with a wooden ramrod that just fits the hole. The clay is pressed down tightly on the cartridge and should fill a depth of about 3 or 4 in. On top of the clay, sand or sharp gravel may be used and pressed down tightly, the tamping being harder toward the surface.

DANGERS OF BLASTING

Ques. 711.—What dangers arise from lack of judgment in placing shots in coal mining? *F.—Pa.* (*B*)

Ans.—If the shot is wrongly placed, the force of the explosion may be partially or almost wholly expended on the air of the workings instead of breaking down the coal. This will occur whenever the line of least resistance measured from the center of the charge to the nearest point on the face of the coal, or to the nearest point where the gases of the explosion can find vent, is less than it should be for the amount of charge employed. A charge may be located too close to an old bore hole or to a crevice or fissure in the coal, causing the shot to "squeal." Or where there is a weak stratum in the coal seam and the shot is not properly placed, the blast will seam out or blow out the weak stratum, leaving the rest of the coal intact. Either of these occurrences may result in a serious mine explosion if there are accumulations of dust or firedamp close to the hole. The charge should always be so located that the line of least resistance is sufficient to absorb, as nearly as possible, the entire energy or force of the explosion.

Ques. 712.—What dangers arise from blasting coal out of the solid? *F.—Pa.* (*B*)

Ans.—In the blasting of coal out of the solid, there is more or less risk of a tight shot, by which is meant a shot where the powder is not given a proper opportunity to perform its work. Blasting off the solid requires the best judgment of an experienced miner, and a thorough knowledge and acquaintance with the kind of coal worked. The inexperienced miner increases the danger of a tight shot by increasing the charge of powder, and the coal is either broken into fine dust and fragments, or the powder blows the tamping and a windy or blown-out shot is the result.

Ques. 713.—In what way is shot firing dangerous in a mine containing inflammable gas? Explain fully. *F.—Pa.* (*B*)

Ans.—The firing of a shot almost invariably produces a certain amount of flame that is projected into the air at the moment of firing. Where inflammable gas is present, it is usually ignited by the flame of the shot and may result in a serious explosion if any considerable body of gas has accumulated at that point. Black powder produces the largest volume of flame, and is the most dangerous in gaseous mines, of all the explosives. The detonating explosives such as dynamite and nitroglycerine, produce a less volume of flame, which is also of less duration. So-called flameless explosives are, perhaps, the safest in mining practice, because the volume of flame produced is reduced to a minimum.

Ques. 714.—What are the dangers due to shot firing in gaseous mines? What precautions are necessary to prevent the same? *F.—Pa.* (*B*)

ANS.—The chief danger is that of igniting the body of gas accumulated at the face, or causing a dust explosion by the ignition of the dust thrown into the air by the force of the blast; or igniting a gas feeder set free by the blast, which may result, if not promptly extinguished, in the ignition of the coal and cause a serious mine fire.

The firing of shots in gaseous mines should be entrusted only to experienced men appointed for that purpose, and must only be done according to law. All shots should be inspected before firing, to avoid, if possible, the occurrence of a blown-out shot. All accumulations of dust and fine coal should be removed from proximity to the face of the coal; the place should be carefully tested for gas before each shot is fired. When the gas is in the coal, to avoid the ignition of the gas, it may be necessary to use safety blasting barrels or tubes and employ touch paper for firing. After firing, the place should be examined to ascertain if the coal or gas has been ignited. In a particularly dry and dusty mine, the vicinity of the shot should be sprinkled with water previous to firing.

QUES. 715.—What would you consider the cause of a flame traveling down a 50-foot room and out to the heading when a coal shot is fired at the face of the room, and what remedy would you apply to prevent such danger? *F.—Pa. (B)*

ANS.—The flame might be produced by three causes acting conjointly: (1) a blown-out shot; (2) a small percentage of inflammable gas at the face of the room; (3) coal dust thrown into the air by the concussion and ignited by the flame of the shot. The inflammable gas will be a mixture of two kinds, the marsh gas in the air and the carbon monoxide produced by the explosion of the powder and distilled from the dust.

To prevent such an occurrence, the roof, sides, and floor of the room should be watered to prevent the dust being thrown into the air by the concussion of the shot.

QUES. 716.—What is the lowest percentage of explosive gas in which you deem it safe to carry on blasting operations in mines? *B.—Pa. (B)*

ANS.—We assume the question intends to ask for the maximum percentage of explosive gas in which blasting operations are safe. This will depend on numerous conditions, such as the character of the workings, nature of the coal, gaseous condition of the air, kind of explosive used. The blasting of coal in mines is dangerous under the best conditions, and an extremely small percentage of gas, assisted by accumulations of dust or fine coal in the vicinity of the shot, especially if the blasting is performed in a soft, inflammable coal, in thin seams or contracted workings, may often lead to serious consequences. Percentages of gas that are not explosive under normal conditions are rendered highly explosive under the pressure of a blast, or in presence of coal dust. When other conditions are favorable, the amount of explosive gas, where blasting is performed, should not exceed, say 2 per cent. When this point is reached, it is the part of wisdom to

increase the volume of air in circulation, to decrease the percentage of gas in the current; but this is not to assert that blasting cannot be performed when a greater percentage of gas is present. In a soft, inflammable coal and in contracted seams, blasting should not be performed when there is more than 1 per cent. of gas present, and then the utmost care should be observed.

PRECAUTIONS IN BLASTING IN GASEOUS AND DUSTY MINES

QUES. 717.—What precautions are necessary to be enforced by a mine foreman, in mines not producing explosive gases, where shot firing is done, to secure the greatest safety to the workmen? *F.—Pa. (B)*

ANS.—All working places should be kept well cleaned and all fine coal and slack should be loaded out; shots should be examined by a competent person before firing; and any shot that is laid too deep on the solid, or charged too heavily, or tamped improperly, should be condemned; the use of coal dust for stemming should not be permitted. The practice of drawing the charge when a shot has missed fire, or firing a second shot in a hole where the previous shot blew out the tamping, should be strictly prohibited. In dusty mines, and especially where the coal is of a flammable nature, water should be used to sprinkle the working place before firing. As an extra precaution, squibs should be used in preference to fuse; but where the latter is employed, only double tape fuse should be allowed, and extra care should be observed not to injure the fuse in tamping. Firing should only be permitted at a specified time, and due warning should be given by previously arranged signals, before any shot is fired. Firing should only be done in rotation, beginning inby of the air, and no one should return to the face to ascertain the cause of a misfire for several hours, owing to the danger of the shot hanging fire.

QUES. 718.—What extra precautions does the law prescribe when blasts are fired in close proximity to an inflammable mixture of air and gas? Describe, in detail, the best method of firing when gas issues from the hole. *F. —Pa. (A)*

ANS.—The extra precaution required by the Anthracite Mine Law of Pennsylvania (Art. 12, Rule 11) reads as follows:

No blast shall be fired in any mine where locked safety lamps are used, except by permission of the mine foreman or his assistant, and before a blast is fired, the person in charge must examine the place and adjoining places and satisfy himself that it is safe to fire such blast before such permission is given.

When a large amount of gas is being given off from the bore hole, the best mode of firing a blast is by using two blasting barrels; laying one barrel in the hole before charging, and inserting the other in the powder cartridge far enough to tie securely. Then tamp or stem lightly for a few inches, taking care that the tamper works smoothly, and when ready, use

safety squibs, known among miners as touch squibs. Insert the squib, after examining, in the barrel leading to the powder and light or touch with a separate piece of touch paper. The other barrel carries the gas away and should be from 8 to 12 in. longer so as to protrude from the hole farther than the one that leads to the powder.

Ques. 719.—Where shots are being fired in mines producing large volumes of explosive gas, what precautions should be adopted in firing the same? *B.—Pa.* (*B*)

Ans.—It is necessary under these conditions that the place be carefully examined for gas and each shot inspected before firing. Shots that are gripped too strongly, or laid too deep on the solid, should be condemned. An ample air-current should be passing the working face at the time of firing. If the seam is very gaseous, safety blasting barrels should be used and the shot should be fired by a piece of touch paper. Fuse should not be used, but squibs should be employed instead. The working face should be kept in a tidy condition and free from all accumulations of dust or fine coal. Not more than two shots should be fired in a working place at one time, unless there is a particularly good current of air at the face. Firing should always be done at the specified time and should begin on the end of the air and proceed in rotation.

Ques. 720.—What are the dangers arising from the use of powder in dry and dusty mines, and how would you guard against them? *M.—B. C., Canada*

Ans.—The danger arising from the use of black powder in a dry and dusty mine is due to the flame that always accompanies the explosion of the powder. Under the best conditions in blasting, this flame projected into the mine workings by the force of the blast is a dangerous element that should be avoided as far as practicable. In the use of black powder, every precaution should be taken to prevent any accumulation of dust and fine coal at the working face; incombustible material should be used for tamping the charge, and where the coal is particularly inflammable, a powder should be chosen as free from flame as possible. In such cases, the flameless powders are to be recommended. When the place is dry and dusty, the face of the coal and the vicinity should be sprinkled with water previous to blasting; and when any gas is present the place should be carefully examined by an authorized and experienced person previous to the firing of each shot. Where the conditions are particularly dangerous in this regard, shot firers should be employed, and the work should be performed after the men have left the mine. All shots considered unsafe should be condemned and not fired.

Ques. 721.—In a mine known to give off explosive gas and where mining machines are used to undercut the coal that is blasted down with powder or other explosive, what precautions would you take, and what is liable to occur even though the safety lamp gives no indication of gas? *B.—Pa.* (*B*)

Ans.—As machine cutting produces much fine coal dust that floats in the air, before shots are fired, any accumulations of gas should be removed and the roof, floor, and sides of the room should be sprinkled with water. All accumulations of dust and fine coal should be loaded out. In the presence of dust, a windy shot or small dust explosion is liable to occur at the face when the common Davy lamp gives no indication of gas being present. A serious mine explosion may occur in blasting a soft, inflammable coal when less than 1 per cent. of gas is present in the air.

Ques. 722.—What is the highest percentage of explosive gas in which you deem it safe to carry on blasting operations in the mine? *B.—Pa. (B)*

Ans.—This will depend on the condition of the mine with respect to dust and the inflammability of the coal. Blasting should not be performed, under the most favorable conditions, where gas is present to an amount exceeding 2 per cent. In a dry and dusty mine, the presence of a much less quantity of gas, say 1 per cent., will be dangerous when blasting, unless the utmost caution is exercised in the care and the examination of the face. When the coal is particularly soft and inflammable, blasting should not be performed if any gas is present except in the smallest quantities, and every precaution must be taken to avoid the accumulation of dust or fine coal at the face.

Ques. 723.—Are there any precautions you could adopt to insure greater safety to the workmen employed in the mine other than that required by the mining law? *B.—Pa. (B)*

Ans.—The general precautions to be adopted are given in answer to Ques. 717. There are numerous details in reference to the handling of explosives, the conducting of blasting operations, the mining of coal, and timbering of airways and working places that should receive the careful attention of the mine foreman and fire-boss in order to render the operation of the mine as safe as possible. Other minor details necessary to safety, but not mentioned in many mine laws are the avoidance of open lights in stables; the manner of conveying powder and other explosives into the mine; charging of holes; the order of succession of firing blasts; forms and methods of timbering. Blasting should be done under the direct charge and guidance of the mine foreman, and the safety of the work will therefore depend on his intelligence and judgment.

LAWS REGULATING BLASTING

Ques. 724.—What are the legal requirements in regard to blasting, to prevent accidents, and what precautions must be exercised in handling explosives in mines? *F.—Pa. (B)*

Ans.—The Bituminous Mine Law requires that no powder or high explosive shall be stored or taken into the mine in greater quantities than required for one shift, except when such amount is less than 5 lb., and it shall be carried in a metallic canister. Not more than 25 lb. of powder, or 10 lb. of other explosives shall be stored in any tipple or weigh office where workmen visit, and no naked lights shall be used while weighing or giving out powder. Where locked safety lamps are used, blasting may only be done with the consent and in the presence of the mine foreman or his assistant. The mine foreman shall see that all coal is properly undermined before being blasted, and shall permit no person to blast coal, rock, or slate, unless satisfied that such person is qualified by experience for such work. The mine inspector shall have power to restrict blasting to a certain hour of the day, if he deems it necessary. A miner must examine the roof and coal after firing each blast. Before firing a blast, he shall notify all persons nearby and give sufficient alarm to warn any person approaching. When handling any explosive, a workman shall place his light at least 5 ft. from such explosive, and in such a position that the air-current cannot convey sparks to it; he shall not smoke while handling explosives.

Ques. 725.—What are the requirements of the mine law in regard to the handling and storage of gunpowder and other explosives in a mine; where should they be kept, and in what quantities? *F.—Pa. (A)*

Ans.—The Anthracite Mine Law prohibits the storing of gunpowder or other explosive in a mine, and limits the quantity of powder a workman shall have at one time in one place, to 25 lb., except where more is required for 1 day's work (Art. 12, Rule 26); and requires that such explosive shall be kept in a locked box at least 10 ft. from the tracks, in all cases where room at such a distance is available. A workman before opening such box, or handling an explosive in any manner, shall place his lamp not less than 5 ft. away, and in such a position that the air-current cannot convey sparks from the lamp to the explosive, and no workman shall approach such box closer than 5 ft. with a lighted lamp or pipe, or any other thing containing fire. Where high explosives other than gunpowder are used in any mine, the manner of storing, keeping, moving, charging, and firing, or in any manner using such explosives, shall be in accordance with special rules as furnished by the manufacturers of the same, such rules to be indorsed by the owner, operator, or superintendent of the mine with his or their official signature.

Ques. 726.—What are the state laws of Indiana relative to the use of powder in coal mines? What steps would you take to enforce these laws, or detect persons who may be violating them? *F.—Ind.*

Ans.—The Indiana Mine Law provides that blasting shall not be done in working hours except only when opening a new mine employing not over twenty men, and being not over 100 yards in any direction from the bottom

of the shaft. In such cases, blasting is permitted twice only during working hours. The law also provides that the firing of shots shall begin inby on the air, and that no shot shall be fired until all the persons inby from such shot shall have passed out. The law also provides that no hole for blasting shall be drilled more than 1 ft. past the end of a cutting or a loose end, and no hole for blasting shall be located more than 5 ft. from a loose end, measured at right angles to the direction of the hole. It also provides that not more than 8 lb. of blasting powder shall be placed or exploded in one hole. A fine of not over $100 nor less than $5, or imprisonment in the county jail not exceeding 6 months nor less than 30 days, is provided for the violation of this act.

To detect violations of the law in reference to the use of powder is a difficult matter. An exact account of the number of holes fired and the powder used by each man may be kept, but this would only show the average charge of powder used. The only certain method is to employ men to inspect, load, and fire the holes.

Ques. 727.—What does the law require in regard to the handling of powder and the charging and firing of shots? *M.—Ill.*

Ans.—Section 20 of the Illinois Mine Law reads as follows:

No blasting powder or other explosives shall be stored in any coal mine, and no workman shall have at any time more than one 25-pound keg of black powder in the mine, nor more than 3 pounds of high explosives.

Place and Manner of Storing.—(*a*) Every person who has powder or other explosives in a mine, shall keep it or them in a wooden or metallic box or boxes securely locked, and said boxes shall be kept at least 10 feet from the track, and no two powder boxes shall be kept within 50 feet of each other, nor shall black powder and high explosives be kept in the same box.

Manner of Handling.—(*b*) Whenever a workman is about to open a box or keg containing powder or other explosive, and while handling the same, he shall place and keep his lamp at least 5 feet distant from said explosive and in such a position that the air-current cannot convey sparks to it, and no person shall approach nearer than 5 feet to any open box containing powder or other explosive with a lighted lamp, lighted pipe, or other thing containing fire.

Copper Tools.—(*c*) In the process of charging and tamping a hole no person shall use any iron- or steel-pointed needle. The needle used in preparing a blast shall be made of copper and the tamping bar shall be tipped with at least 5 inches of copper. No coal dust nor any material that is inflammable or that may create a spark shall be used for tamping, and some soft material must always be placed next to the cartridge or explosive.

Use of Squibs.—(*d*) A miner who is about to explode a blast with a manufactured squib shall not shorten the match, saturate it with mineral oil nor ignite it except at the extreme end; he shall see that all persons are out of danger from the probable effects of such shot, and shall take measures to prevent any one approaching, by shouting "fire!" immediately before lighting the fuse.

Not More Than One Shot at a Time.—(*e*) Not more than one shot shall be ignited at the same time in any one working place, unless the firing is done by electricity or by fuses of such length that neither of the shots will explode in less than 3 minutes from the time they are lighted. When

successive shots are to be fired in any working place in which the roof is broken or faulty, the smoke must be allowed to clear away and the roof must be examined and made secure between shots.

Missed Shots.—(*f*) No person shall return to a missed shot until 5 minutes have elapsed, unless the firing is done by electricity, and then only when the wires are disconnected from the battery.

Dusty Mines.—(*g*) In case the galleries, roadways, or entries of any mine are so dry that the air becomes charged with dust, the operator of such mine must have such roadways regularly and thoroughly sprayed, sprinkled, or cleaned, and it shall be the duty of the inspector to see that all possible precautions are taken against the occurrence of explosions which may be occasioned or aggravated by the presence of dust.

QUES. 728.—What is stated in the General Rules of the Coal Mines Regulation Act, British Columbia, regarding gunpowder or other explosives used in mines? *B.—B. C., Canada*

ANS.—General Rule 9 provides that gunpowder or other explosives: (*a*) Shall not be stored in a mine. (*b*) Shall not be taken into a mine except in a case or canister containing not more than 4 pounds. (*c*) No workman shall have in use at one time in any one place more than one such canister. (*d*) No iron or steel pricker or tamping rod or stemmer shall be used, and no person shall have in his possession in a mine, such an iron or steel pricker, tamping rod, or stemmer. (*e*) No explosive shall be forcibly pressed into a hole of insufficient size, or unrammed when a hole misses fire except with the sanction and under the supervision of a shot examiner, and then only when another hole cannot be bored at a distance of at least 2 feet from the charged hole as required by the Act. (*f*) No explosive shall be taken into or be in the possession of any person in any mine, except in cartridges, and shall not be used therein except by or under the direction of a competent person appointed for the purpose of examining and supervising all shots. Such person before firing or permitting a shot to be fired shall examine all places within a radius of 25 yards and find them safe. (*g*) This rule applies alike to all panels or divisions of a mine as to a separate mine, whenever such panel or division has an independent intake and return airway.

CHAPTER VII

ELEMENTARY PRINCIPLES AND CALCULATIONS OF MINE VENTILATION

RUBBING SURFACE OF AN AIRWAY

QUES. 800.—Find the number of square feet of rubbing surface in an airway 4 feet high, 9 feet wide, and 1,000 feet long. *F_1.—Ala.*

ANS.— $2(4+9)\times 1{,}000 = 26{,}000$ sq. ft.

QUES. 801.—A rectangular airway is 6 feet high, 12 feet wide, and 2,500 feet long; what is the rubbing surface in square feet? *F.—Pa. (A)*

ANS.—The rubbing surface of this airway is

$$2(6+12)\times 2{,}500 = 90{,}000 \text{ sq. ft.}$$

QUES. 802.—What is the rubbing surface of a road 8 feet 6 inches wide, 6 feet 9 inches high, and 3,000 feet long? *F_1.—Ala.*

ANS.— 8 ft. 6 in. = 8.5 ft., 6 ft. 9 in. = 6.75 ft. For the rubbing surface we have

$$s = 2(8.5+6.75)\times 3{,}000 = 91{,}500 \text{ sq. ft.}$$

QUES. 803.—What is the rubbing surface in a circular shaft 15 feet in diameter and 1,200 feet deep, divided into two equal compartments by a partition, the thickness of which may be neglected? *M.—Ill.*

ANS.—The perimeter of the total rubbing surface in both compartments of this shaft is equal to the circumference plus twice the diameter, or

$$3.1416\times 15+2\times 15 = 77.124 \text{ ft.};$$

and the rubbing surface is, therefore,

$$77.124\times 1{,}200 = 92{,}548+ \text{ sq. ft.}$$

QUES. 804.—Two airways, one circular and the other square, each have an area of 81 square feet; the length of each is 2,500 feet; what is the difference in the rubbing surfaces of the two airways? *I.—Pa. (A)*

Ans.—The rubbing surface of the square airway is

$$4\sqrt{81}\times 2{,}500 = 90{,}000 \text{ sq. ft.};$$

and the rubbing surface of the circular airway is equal to

$$3.1416\sqrt{\frac{81}{.7854}}\times 2{,}500 = 79{,}760+$$

The difference in the rubbing surfaces is, therefore,

$$90{,}000-79{,}760 = 10{,}240 \text{ sq. ft.}$$

Ques. 805.—Find the rubbing surfaces of three airways each 6,000 feet long and all having the same sectional area, 75 square feet. The forms of the three sections are as follows: the first, A, is rectangular, 5 feet high and 15 feet wide; the second, B, is square; and the third, C, is circular. F_1.—*Ala.*

Ans.—The rubbing surface for each of these airways is found as follows:

$$A,\ 2(5+15)\times 6{,}000 = 240{,}000 \text{ sq. ft.};$$

$$B,\ 4\sqrt{75}\times 6{,}000 = 207{,}846+ \text{ sq. ft.};$$

$$C,\ 3.1416\sqrt{\frac{75}{.7854}}\times 6{,}000 = 184{,}198+ \text{ sq. ft.}$$

AREA OF AN AIRWAY

Ques. 806.—What do you mean by the sectional area of an airway? F_1.—*Ala.*

Ans.—The sectional area of an airway is the area of its average cross-section.

Ques. 807.—What is the area of a road measuring 7 feet 3 inches by 6 feet 6 inches? F_1.—*Ala.*

Ans.— 7 ft. 3 in. = 7.25 ft., and 6 ft. 6 in. = 6.5 ft. Then, for the area,

$$a = 7.25\times 6.5 = 47.125 \text{ sq. ft.}$$

Ques. 808.—What is the area of an airway where the breadth of the top is 5 feet 9 inches, middle 7 feet 9 inches, bottom 7 feet 6 inches, and the height 9 feet? *F.—Pa.* (*B*)

Ans.—For the area of the upper half of this airway,

$$\frac{5.75+7.75}{2}\times\frac{9}{2} = 6.75\times 4.5 = 30.375 \text{ sq. ft.};$$

and for the area of the lower half of the airway,

$$\frac{7.75+7.5}{2}\times\frac{9}{2} = 7.625\times 4.5 = 34.3125 \text{ sq. ft.}$$

The total area of airway is

$$30.375+34.3125 = 64.6875 \text{ sq. ft.}$$

QUES. 809.—Fifty thousand cubic feet of air per minute is passing in an airway, at a velocity of 8 feet per second; assuming the airway to be square, find its area and perimeter. *F.—Pa. (A)*

ANS.—The area of the airway in this case is

$$a = \frac{50{,}000}{8 \times 60} = 104.25 \text{ sq. ft.};$$

and, assuming a square airway, its perimeter o is

$$o = 4\sqrt{104.25} = 40.83+ \text{ ft.}$$

QUES. 810.—What is the rubbing surface per square foot of section, for an airway 7 feet high, 11 feet wide, and 4,672 feet long? *F_1.—Ala.*

ANS.—The rubbing surface per square foot of section in this case is

$$\frac{2(7+11) \times 4{,}672}{7 \times 11} = 2{,}184+ \text{ sq. ft.}$$

QUES. 811.—An airway is 7 feet high and 8 feet wide, and the rubbing surface per square foot of section is 2,684 square feet; what is the length of the airway? *F_1.—Ala.*

ANS.—The total rubbing surface of this airway is

$$2{,}684(7 \times 8) = 150{,}304 \text{ sq. ft.}$$

Dividing this rubbing surface by the perimeter $2(7+8) = 30$ ft., we have, for the length of the airway,

$$150{,}304 \div 30 = 5{,}010+ \text{ ft.}$$

PRESSURE

QUES. 812.—What is meant by the terms ventilating pressure, water gauge, and resistance of air? *F.—Pa. (A)*

ANS.—The term ventilating pressure refers to the pressure producing ventilation. It is the total pressure on the air as indicated by the expression $p\,a$; that is, the pressure on a square foot multiplied by the area, in square feet. The unit of ventilating pressure, or the pressure per square foot of area, producing ventilation, is, however, often spoken of as the ventilating pressure, in which case $p\,a$ is called the total pressure. The water gauge is often used to describe the ventilating pressure, per square foot of sectional area, in inches of water column, the same as the term motive column describes the same pressure in feet of air column.

The term resistance, as applied to the circulation of air in an airway, refers to the friction developed by the passing of the air-current through the airway. The rubbing of the air on the sides, top, and bottom of the airway causes friction or resistance to the passage of the current. This resistance is proportional to the extent of the rubbing surface, and the

square of the velocity of the current; because, when the velocity is doubled, the same quantity of air touches twice the amount of rubbing surface, or meets with twice the number of resisting particles, and strikes each particle with double the force; hence, the resistance offered when the velocity is doubled is $2 \times 2 = 4$ times the original resistance. The unit of resistance or the coefficient of resistance (k) is the amount of resistance, in pounds, offered by 1 sq. ft. of rubbing surface to a current having a velocity of 1 ft. per min. The total resistance is therefore obtained by multiplying this unit resistance (k) by the number of square feet of rubbing surface (s), and that product by the square of the velocity (v^2). The total resistance, as mentioned, is equal to the ventilating pressure, or the total pressure on the airway ($p\,a$). Hence, for the total resistance we write $R = p\,a = k\,s\,v^2$.

QUES. 813.—What is meant by the formula $p\,a = k\,s\,v^2$? *M.—Ill.*

ANS.—The first member of this formula $p\,a$ is the expression for the total pressure exerted by a ventilating current on the entire sectional area of the airway; this is the total ventilating pressure or the pressure producing circulation and is equal to the unit pressure p per square foot multiplied by the area, in square feet. The second member of the formula $k\,s\,v^2$ is the expression for the resistance of the airway, or the resistance against which the total ventilating pressure is exerted and to which it is equal. It is the resistance of the airway that establishes and maintains the pressure set up by the action of the ventilator. The unit of resistance k is the resistance offered by a unit of rubbing surface (1 sq. ft.), to the passage of a current having a unit velocity (1 ft. per sec.); and this unit resistance multiplied by the actual rubbing surface and the square of the actual velocity gives the total resistance of the airway.

NOTE.—There is a wide difference in the values given the coefficient of friction k by different authorities. Moreover, it is possible to determine this value only approximately, since the exact value for any particular mine depends on the local conditions. The values most frequently used are those given by W. Fairley, .00000001, and by J. J. Atkinson, .0000000217. In order to simplify calculations in ventilation, a value of $k = .00000002$ will be used in this book unless it is distinctly stated in the problem that some other coefficient is used.

QUES. 814.—Define the term coefficient of friction. *I.—Ia.*

ANS.—The coefficient of friction is another term for the unit of resistance of the airway; that is, the resistance offered by 1 sq. ft. of rubbing surface to a current having a velocity of 1 ft. per min.

QUES. 815.—Explain the formula $p = \frac{k\,s\,v^2}{a}$, and its application. *F.—Pa. (A)*

ANS.—In this formula, which gives the pressure in terms of the airway and the quantity, p is the unit of ventilating pressure, in pounds per square foot; k is the unit of resistance or coefficient of friction and is equal to .00000002; s is the rubbing surface, and equals the product of the perimeter and length of the airway, thus, $s = l\,o$; v is the velocity of the air-current

in feet per minute; a is the sectional area of the airway, and equals the product of the height by the average width. The application of the formula is shown by the following question:

QUES. 816.—An airway is 6 ft. × 10 ft. in section, and 5,000 feet in length; using the coefficient of friction $k = .00000002$ what pressure will be required to pass 60,000 cubic feet of air through this airway per minute? *I.—Ia.*

ANS.—The area a is $6 \times 10 = 60$ sq. ft.; the rubbing surface s is

$$l\,o = 5{,}000 \times 2(6+10) = 160{,}000 \text{ sq. ft.}$$

The velocity will be

$$v = \frac{q}{a} = 60{,}000 \div 60 = 1{,}000 \text{ ft. per min.}$$

Then applying the formula for pressure

$$p = \frac{k\,s\,v^2}{a} = \frac{.00000002 \times 160{,}000 \times 1{,}000^2}{60} = 53\tfrac{1}{3} \text{ lb. per sq. in.}$$

QUES. 817.—What pressure will be necessary to force 20,000 cubic feet of air through an airway 14 feet wide, 6 feet high, and 3,000 feet long? *F.—Pa. (A)*

ANS.—The formula for pressure in terms of the airway k, l, o, and a, and the quantity of air passing q, is

$$p = \frac{k\,l\,o\,q^2}{a^3}$$

Substituting the given values in this formula, we have, using the Atkinson coefficient ($k = .0000000217$),

$$p = \frac{.0000000217 \times 3{,}000 \times 2(6+14) \times 20{,}000^2}{(6 \times 14)^3} = 1.75+ \text{ lb. per. sq. ft}$$

WATER GAUGE

QUES. 818.—The pressure producing ventilation being 10.4 pounds per square foot, what is the water gauge? *F.—Pa. (A)*

ANS.—An inch of water gauge is equivalent to a pressure of 5.2 lb. per sq. ft., and therefore a pressure of 10.4 lb. per sq. ft. corresponds to

$$10.4 \div 5.2 = 2 \text{ in. of water gauge}$$

QUES. 819.—Explain the constant 5.2 used in connection with water-gauge calculations.

ANS.—The constant 5.2 is the weight of water overlying 1 sq. ft. of area, 1 in. deep, and represents the pressure per square foot due to 1 in. of water gauge.

QUES. 820.—What will be the reading of the water gauge when the pressure per square foot is 20 pounds? *F.—Ia.*

Ans.—Each inch of water guage, in mine ventilation, indicates a pressure per square foot of 5.2 lb. The water gauge corresponding to a pressure of 20 lb. is calculated by the formula

$$i = \frac{p}{5.2} = \frac{20}{5.2} = 3.84+ \text{ in.}$$

Ques. 821.—What is the ventilating pressure in pounds per square foot when the water gauge reads 2.4 inches? *F.—Pa. (A)*

Ans.— $2.4 \times 5.2 = 12.48$ lb. per sq. ft.

Ques. 822.—What amount of pressure, in inches of water gauge, will be required to overcome the friction of the rubbing surface of an airway 8 feet high, 14 feet broad, and 5,790 feet long, the velocity of the air-current being 1 foot per minute? *F_1.—Ala.*

Ans.—Assume the coefficient of friction, $k = .00000002$ lb. The rubbing surface in this airway is

$$2(8+14) \times 5{,}790 = 254{,}760 \text{ sq. ft.;}$$

and the total resistance of the airway to a current having a velocity of 1 ft. per min. is, therefore,

$$254{,}760 \times .00000002 = .0050952 \text{ lb.}$$

Dividing this resistance by the area of the airway, and that result by 5.2, the required water gauge is

$$i = \frac{.0050952}{8 \times 14 \times 5.2} = .000008577+ \text{ in.}$$

Ques. 823.—What water gauge will be absorbed by the resistance of a circular shaft 15 feet in diameter, 1,200 feet deep, divided into two compartments by a central partition, when a current of 150,000 cubic feet of air is passing down the shaft? Use the Fairley coefficient in making this calculation. *M.—Ill.*

Ans.—The rubbing surface of this shaft, as calculated in answer to Ques. 803, is 92,548 sq. ft.; the area of the shaft is

$$a = .7854\,d^2 = .7854 \times 15^2 = 176.7+ \text{ sq. ft.}$$

Substituting these values and the given ones in the formula, for pressure in terms of the quantity, and dividing by 5.2 to reduce to inches of water gauge:

$$i = \frac{k\,s\,v^2}{5.2a^3} = \frac{.00000001 \times 92{,}548 \times 150{,}000^2}{5.2 \times 176.7^3} = .725+ \text{ in.}$$

Ques. 824.—The rubbing surface of an airway is equal to 152,280 square feet, the velocity of the current is 800 feet per minute, the ventilating pressure is equal to 4.26 inches of water gauge; what is the area of section of this airway in square feet? *F_1.—Ala.*

Ans.—The pressure per square foot corresponding to 4.26 in. of water gauge is $5.2 \times 4.26 = 22.15$ lb. The total resistance in this airway is calculated as follows:

$$pa = ksv^2 = .00000002 \times 152{,}280 \times 800^2 = 1{,}949.184 \text{ lb.}$$

Finally, dividing the total resistance by the resistance per square foot of sectional area, the area of section is

$$1{,}949.184 \div 22.15 = 87.999+ \text{ sq. ft.}$$

Ques. 825.—There are 10,000 cubic feet of air passing along an airway having a rubbing surface of 24,000 square feet and a sectional area of 20 square feet; what is the water gauge?

I.—Pa. (A)

Ans.—The water gauge in this case is determined by the formula,

$$i = \frac{ksq^2}{5.2a^3} = \frac{.00000002 \times 24{,}000 \times 10{,}000^2}{5.2 \times 20^3} = 1.15+ \text{ in.}$$

VELOCITY OF AIR IN AN AIRWAY

Ques. 826.—There is passing through an airway 35,000 cubic feet of air per minute, what will be the velocity per second if the size of the airway is 7.5 ft. × 5.5 ft.? *F.—Pa. (B)*

Ans.—The area of this airway is $7.5 \times 5.5 = 41.25$ sq. ft.; and the velocity of the air is, then,

$$v = \frac{q}{a} = 35{,}000 \div 41.25 = 848.4+ \text{ ft. per min.,}$$

or

$$848.4 \div 60 = 14.14 \text{ ft. per sec.}$$

Ques. 827.—If 55,000 cubic feet of air per minute is passing through a circular shaft 10 feet in diameter, what is the velocity per second? *F.—Pa. (B)*

Ans.— $$v = \frac{q}{a} = \frac{55{,}000}{60(.7854 \times 10^2)} = 11.67+ \text{ ft. per sec.}$$

Ques. 828.—The volume of air passing through a tunnel having a semicircular arched roof of 4 feet radius, the springing line of the arch being 4 feet above the floor, is 23,625 cubic feet per minute; what is the velocity of the current, in feet per minute?

I.—Pa. (A)

Ans.—The area of this airway is calculated as follows:

$$(4 \times 8) + \frac{.7854 \times 8^2}{2} = 57.13+ \text{ sq. ft.}$$

Then, for the velocity, $v = \frac{q}{a} = 23{,}625 \div 57.13 = 413.5+$ ft. per min.

QUES. 829.—The total rubbing surface of a square airway being 160,000 square feet; the length of the airway, 5,000 feet; the quantity of air passing, 80,000 cubic feet per minute; what is the velocity of the air-current, in feet per minute? *F.—Pa. (B)*

ANS.—The perimeter of this airway is $o = \frac{s}{l} = 160{,}000 \div 5{,}000 = 32$ ft. The airway being square, its height or breadth is $32 \div 4 = 8$ ft. The area of the cross-section of this airway is then $8^2 = 64$ sq. ft., and the velocity of the air-current is

$$80{,}000 \div 64 = 1{,}250 \text{ ft. per min.}$$

QUES. 830.—The entry of a mine is 7 ft. × 10 ft. in section, and 6,720 feet long; what is the velocity of the ventilating current passing through this entry when the water gauge stands at 2 inches? *I.—Ia*

ANS.—The velocity in this case is calculated by the formula

$$v = \sqrt{\frac{p\,a}{k\,s}}$$

or since $p = 5.2 \times i = 5.2 \times 2 = 10.4$ lb., the required velocity is

$$v = \sqrt{\frac{10.4(7 \times 10)}{.00000002 \times 2(7+10)6{,}720}} = 399.1+ \text{ ft. per min.}$$

QUES. 831.—If the square of the velocity of air rushing into a vacuum through an orifice at ordinary atmospheric pressure at sea level (14.7 pounds per square inch) is 700,000, corresponding to a pressure of $144 \times 14.7 = 2{,}116.8$ pounds per square foot, what is the square of the velocity of air passing through an orifice under a pressure equal to 1 inch water gauge? *I.—Pa. (A)*

ANS.—An inch of water gauge corresponds to a pressure of 5.2 lb. per sq. ft., making the absolute pressure for this gauge $2{,}116.8 + 5.2 = 2{,}122$ lb. per sq. ft. But the square of the velocity of air flowing through an orifice into a vacuum varies directly as the absolute pressure on the air; therefore, for the required square of the velocity, in this case,

$$v^2 = 700{,}000 \times \frac{2{,}122}{2{,}116.8} = 701{,}719+$$

NOTE.—The square of the velocity of air, in feet per second, rushing into a vacuum under a pressure of 14.7 lb. per sq. in. at a temperature of 65° F., is practically 1,800,000 instead of 700,000, as stated in this question, making the square of the velocity due to a 1-in. water gauge 1,804,424+.

QUES. 832.—If the water gauge shows a depression of ½ inch, what is the velocity of air per minute when a cubic foot of air weighs .076 pound? *F.—Pa. (A)*

Ans.—The head of air column (h) in feet, corresponding to a given water gauge (i) in inches, calling the weight of 1 cu. ft. of air w, is

$$h = \frac{5.2\times i}{w} = \frac{5.2\times \frac{1}{2}}{.076} = 34.21 + \text{ ft.}$$

The theoretical velocity due to this head of air column is

$$v = \sqrt{2g\,h} = \sqrt{2\times 32.16\times 34.21} = 46.9 + \text{ ft. per sec.}$$

This is not, however, the velocity of the airway due to this pressure. The theoretical velocity means simply the velocity due to a certain head, where no resistance is encountered, as when air flows into a vacuum. The actual velocity in an airway, due to any pressure, is always less than the theoretical velocity due to the same pressure, and depends on the resistance of the airway.

QUANTITY OF AIR PASSING IN AN AIRWAY

Ques. 833.—What are the factors determining the quantity of air passing in a mine at any given time? *M.—Ill.*

Ans.—The area of the transverse section of the airway through which the current passes, and the velocity of the current through the given section. The velocity depends on the pressure or power producing the circulation of air and the resistance offered by the airway to the passage of the current.

Ques. 834.—How many cubic feet of air pass per minute along an airway 6 feet high and 10 feet wide, the velocity being 450 feet per minute? *F_1.—Ala.*

Ans.—The area of this airway is $6\times 10 = 60$ sq. ft., and the quantity of air in circulation is

$$q = a\,v = 60\times 450 = 27{,}000 \text{ cu. ft. per min.}$$

Ques. 835.—The inlet opening of a mine is 7 feet 6 inches by 8 feet 9 inches, the velocity of the air is 512 feet per minute, what quantity of air, in cubic feet, is passing into this mine in 1 hour? *F.—Pa. (B)*

Ans.— $(7.5\times 8.75)512\times 60 = 2{,}016{,}000$ cu. ft.

Ques. 836.—Where the airway is 10 feet 5 inches wide, and 6 feet 9 inches high, and the velocity of air 450 feet per minute, what is the area of the airway, and what quantity of air is passing per minute? *F.—Pa. (A)*

Ans.—As the width of the airway (10 ft. 5 in.) cannot be expressed as an exact decimal of a foot, it is better to calculate the area of the airway in square feet, by first reducing the given dimensions to inches, and then dividing their product by 144; thus, 10 ft. 5 in. = 125 in., 6 ft. 9 in. = 81 in.; and

$$\frac{125\times 81}{144} = 70\tfrac{5}{16} \text{ sq. ft.} \quad 70\tfrac{5}{16}\times 450 = 31{,}641 \text{ cu. ft. per min}$$

QUES. 837.—What is the area of a gangway 8 feet wide at top, 10 feet wide at bottom, and 7 feet high? How much air is passing in this gangway, if the anemometer makes 165 revolutions per minute? *F.—Pa. (A)*

ANS.—The area of this gangway being a trapezoid is

$$7\left(\frac{8+10}{2}\right) = 63 \text{ sq. ft.}$$

Since the constant for the anemometer is not stated, it may be neglected and each revolution of the anemometer assumed to correspond to 1 lineal foot of air travel. Then the quantity of air in circulation is

$$q = a\,v = 63\times 165 = 10{,}395 \text{ cu. ft. per min.}$$

QUES. 838.—The anemometer makes 120 revolutions per minute, in an airway that measures 8 feet 6 inches at the top, and 10 feet 6 inches at the bottom, and is 7 feet high; what is the quantity of air passing per minute? *F.—Pa. (A)*

ANS.—As the area of section is in the form of a trapezoid, first find the mean breadth by adding the top and bottom breadths together, and dividing the sum by 2; then the area of section is $\frac{8.5+10.5}{2}\times 7 = 66.5$ sq. ft. If this area of section is multiplied by the velocity, in feet per minute, the product will be the quantity of air passing per minute, according to the formula

$$q = a\,v = 66.5\times 120 = 7{,}980 \text{ cu. ft. per min.}$$

QUES. 839.—Find the quantity of air passing per minute in an airway 14 feet 6 inches by 6 feet 9 inches when the anemometer registers 542 revolutions per minute. *F.—Pa. (A)*

ANS.—Since 14 ft. 6 in. equals 14.5 feet, and 6 ft. 9 in. equals 6.75 feet, the area of this airway is $14.5\times 6.75 = 97.875$ sq. ft.; and the quantity of air is then

$$q = a\,v = 97.875\times 542 = 53{,}048+ \text{ cu. ft. per min.}$$

QUES. 840.—In a timbered airway, the collars measure 7 feet between notches and the spread of the legs is 10 feet wide at the bottom, the clear height from the top of rail to the under side of the collar being 6 feet and the velocity of the air 400 feet per minute, what is the sectional area of the airway, and what is the quantity of air passing per minute? *I.—Pa. (A)*

ANS.—The sectional area being a trapezoid,

$$a = 6\left(\frac{7+10}{2}\right) = 51 \text{ sq. ft.};$$

and $$q = a\,v = 51\times 400 = 20{,}400 \text{ cu. ft. per min.}$$

QUES. 841.—In a gangway having a 7-foot collar, 12-foot spread, and 7½ feet high, what is the area of section? What

quantity of air is passing per minute, when the current has a velocity of 325 feet per minute? *F.—Pa. (A)*

ANS.—The area of this airway is

$$a = 7.5\left(\frac{7+12}{2}\right) = 71.25 \text{ sq. ft.}$$

The quantity of air passing per minute is

$$q = a\,v = 71.25 \times 325 = 23{,}156+ \text{ cu. ft. per min.}$$

QUES. 842.—In an airway that has three sides, 6, 8, and 10 feet, respectively, and is 900 yards long, what is the area, perimeter, and rubbing surface? What quantity of air will be passing in this airway with a velocity of 425 feet per minute? *F.—Pa. (A)*

ANS.—The sectional area of this airway is found by the following

Rule.—*From one-half the perimeter of the airway subtract each side separately; multiply together the three remainders thus found and the half perimeter, and extract the square root of the product; the result is the area required.*

Or, expressed as a formula, calling the area A, and the sum of the three sides a, b, and c, S,

$$A = \sqrt{\frac{S}{2}\left(\frac{S}{2}-a\right)\left(\frac{S}{2}-b\right)\left(\frac{S}{2}-c\right)}$$

and in this case substituting the given values, since $\frac{S}{2} = \frac{6+8+10}{2} = 12$ ft.

$$A = \sqrt{12(12-6)(12-8)(12-10)} = \sqrt{576} = 24 \text{ sq. ft.}$$

The perimeter of this airway, or the sum of its sides, is

$$6+8+10 = 24 \text{ ft.}$$

The length of the airway being 900 yd., the rubbing surface is

$$s = 24 \times 900 \times 3 = 64{,}800 \text{ sq. ft.}$$

The quantity of air passing in this airway when the velocity is 425 ft. per min. is

$$24 \times 425 = 10{,}200 \text{ cu. ft. per min.}$$

NOTE.—This solution for finding the area of a triangle when the three sides are known, will apply to any case, whatever the lengths of the sides. We note, however, in this case, the sides 6, 8, and 10 bear the same relation to each other as the numbers 3, 4, and 5, which are used to construct a right triangle. The angle at the vertex of this triangle, or the angle opposite the longest side (see Fig. 1), is, therefore, a right angle and the area of the triangle may be found by multiplying the side 8 by ½ of the side 6; thus,

$$8 \times \frac{6}{2} = 24 \text{ sq. ft. as found before.}$$

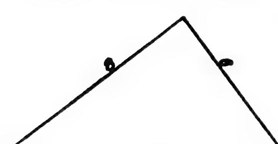


FIG. 1

QUES. 843.—What quantity of air will be passed through an airway 6 ft. × 9 ft. × 3,000 ft. by a pressure of 4½ pounds per square foot, using the Fairley coefficient of friction, $k = .00000001$? *M.—Ill.*

ANS.—The quantity in this case is given by the formula

$$q = a\sqrt{\frac{a\,p}{k\,s}}$$

First calculate the area and the rubbing surface; thus, $a = 6\times 9 = 54$ sq. ft.; and $s = 2(6+9)\times 3{,}000 = 90{,}000$ sq. ft. Then, substituting in the formula these and the values given in the problem, the required quantity is

$$q = 54\sqrt{\frac{54\times 4.5}{.00000001\times 90{,}000}} = 28{,}059+ \text{ cu. ft. per min.}$$

WORK IN VENTILATION

QUES. 844.—What is meant by a unit of work?

M.—B. C., Canada

ANS.—A unit of work is the work performed when a unit pressure or load is moved through a unit distance. The units adopted in English and American practice are the pound and the foot, making the unit of work the work performed when a pressure of 1 lb. moves through a distance of 1 ft., or a weight of 1 lb. is raised through a vertical height of 1 ft. This unit of work is called a foot-pound.

QUES. 845.—How many units of work does a man weighing 150 pounds perform when ascending a hill 60 feet high?

M.—B. C., Canada

ANS.—Disregarding friction, the work performed is

$$150\times 60 = 9{,}000 \text{ ft.-lb.}$$

QUES. 846.—What is meant by the term horsepower?

H.—Ia.

ANS.—The power required to perform 33,000 units of work in 1 minute of time. For example, 1 H. P. is necessary to raise a weight of 33,000 lb. through a vertical height of 1 foot in 1 minute of time; or a weight of 1 lb., 33,000 feet; or 33 lb., 1,000 feet, etc.

QUES. 847.—The quantity of air passing in an airway is 120,000 cubic feet per minute, and the water gauge produced is 2 inches; what are the units of work performed each minute, and the horsepower producing the circulation in this airway? *F.—Pa. (A)*

ANS.—Let u = the units of work required to pass a quantity of air q, in cubic feet per minute, against a pressure p, in pounds per square foot. Then, the work performed each minute in producing this circulation of air is given by the formula

$$u = q\,p = 120{,}000\times 2\times 5.2 = 1{,}248{,}000 \text{ ft.-lb.};$$

and the horsepower performing this work each minute is given by the formula

$$H = \frac{u}{33{,}000} = 1{,}248{,}000\div 33{,}000 = 37.818+ \text{ H. P.}$$

QUES. 848.—If the quantity of air passing in an airway is 60,000 cubic feet a minute, and the water gauge is 2 inches, what is the horsepower producing the circulation? *F.—Pa. (A)*

ANS.—If the quantity, in cubic feet per minute, is multiplied by the pressure in pounds per square foot, corresponding to 2 in. of water gauge, the product will be the units of work performed each minute; and if this work per minute is then divided by 33,000, the quotient obtained will be the required horsepower, thus,

$$H = \frac{q\,p}{33{,}000} = \frac{60.000(2\times 5.2)}{33{,}000} = 18.9+ \text{ H. P.}$$

QUES. 849.—The velocity of the air in an airway 8 ft. × 8 ft. is 10 feet per second, when the water gauge is 1.4 inches; what will be the water gauge if the velocity is increased to 12 feet per second? What will be the units of work performed each minute, and the horsepower producing the circulation in each case? *F.—Pa. (B)*

ANS.—In any circulation, under other like conditions, the pressure varies as the square of the velocity, or the pressure ratio is equal to the square of the velocity ratio; and calling the required water gauge x,

$$\frac{x}{1.4} = \left(\frac{12}{10}\right)^2 = 1.2^2;$$

and $$x = 1.4\times 1.2^2 = 2.016, \text{ say 2 in.}$$

The units of work performed each minute in circulating a quantity of air

$$q = a\,v = (8\times 8)(60\times 10) = 38{,}400 \text{ cu. ft. per min.}$$

against a pressure

$$p = 5.2(i) = 5.2\times 1.4 = 7.28 \text{ lb. per sq. ft.}$$

is given by the formula

$$u = q\,p = 38{,}400\times 7.28 = 279{,}552 \text{ ft.-lb.},$$

and the horsepower required for this work is, then,

$$H = \frac{u}{33{,}000} = \frac{279{,}552}{33{,}000} = 8.47+ \text{ H. P.}$$

In like manner, in the second case,

$$q = a\,v = (8\times 8)(60\times 12) = 46{,}080 \text{ cu. ft. per min.}$$

and $$p = 5.2(i) = 5.2\times 2 = 10.4 \text{ lb. per sq. ft.}$$

and substituting these values, for the work

$$u = q\,p = 46{,}080\times 10.4 = 479{,}232 \text{ ft.-lb.}$$

and for the horsepower

$$H = \frac{u}{33{,}000} = \frac{479{,}232}{33{,}000} = 14.522+ \text{ H. P.}$$

QUES. 850.—If the quantity of air passing in a mine is 120,000 cubic feet per minute under a water gauge of 1 inch, what is the horsepower producing ventilation? *F_1.—Ala.*

ANS.— $$H = \frac{q\,p}{33{,}000} = \frac{120{,}000(5.2\times 1)}{33{,}000} = 18.9+ \text{ H. P.}$$

QUES. 851.—The water gauge in a certain mine is 1.5 inches, the quantity of air in circulation, 85,000 cubic feet per minute; find the horsepower on the air. *F.—Pa. (A)*

ANS.—The horsepower of any circulation is found by dividing the product of the quantity, in cubic feet per minute, and the pressure, in pounds per square foot, by 33,000; thus,

$$H = \frac{q\,p}{33{,}000} = \frac{85{,}000(5.2 \times 1.5)}{33{,}000} = 20.09+ \text{ H. P.}$$

QUES. 852.—The quantity of air produced by a fan is 120,000 cubic feet per minute and the water gauge is 2 inches, what is the horsepower producing ventilation? *F.—Pa. (A)*

ANS.—The horsepower on the air in this circulation is

$$\frac{120{,}000 \times (2 \times 5.2)}{33{,}000} = 37.8 \text{ H. P.}$$

This is the horsepower applied to the air, or the horsepower producing the circulation, but is not the power applied to the fan shaft. Assuming an efficiency of 85 per cent. for the fan, the horsepower applied to the fan shaft is $37.8 \div .85 = 44.5$ H. P. Finally, assuming an efficiency of 90 per cent. for the engine driving the fan, the rated horsepower of the engine is

$$44.5 \div .90 = 49.4 \text{ H. P.}$$

QUES. 853.—If the modulus of the machinery producing ventilation be 62, what horsepower must be performed in maintaining a circulation of 120,000 cubic feet of air per minute, against a water gauge of 1.39 inches? *I.—Ia.*

ANS.—Assuming that by modulus is meant the efficiency of the ventilating machinery, this being 62 per cent., the horsepower concerned in this circulation is calculated as follows:

$$H = \frac{q\,p}{33{,}000} = \frac{120{,}000 \times (5.2 \times 1.39)}{.62 \times 33{,}000} = 42.393 \text{ H. P.}$$

QUES. 854.—An airway is 14 ft. × 10 ft. × 6,000 ft., the quantity of air passing per minute is 45,000 cubic feet; find the pressure, water gauge, and horsepower, using the Atkinson coefficient. *M.—B. C., Canada*

ANS.—

$$p = \frac{k\,s\,q^2}{a^3} = \frac{.0000000217 \times 2(14+10) \times 6{,}000 \times 45{,}000^2}{(14 \times 10)^3} = 4.612 \text{ lb. per sq. ft.}$$

$$i = \frac{p}{5.2} = \frac{4.612}{5.2} = .88+ \text{ in.}$$

$$H = \frac{q\,p}{33{,}000} = \frac{45{,}000 \times 4.612}{33{,}000} = 6.289+ \text{ H. P.}$$

QUES. 855.—An airway 8 ft. × 12 ft. × 4,000 ft. has 28,800 cubic feet of air passing per minute; find the rubbing surface, pressure, and horsepower. *F.—Pa. (A)*

Ans.—The rubbing surface in this airway is

$$s = l\,o = 2(8+12)\times 4{,}000 = 160{,}000 \text{ sq. ft.}$$

The pressure per square foot is

$$p = \frac{k\,s\,q^2}{a^3} = \frac{.00000002\times 160{,}000\times 28{,}800^2}{(8\times 12)^3} = 3 \text{ lb.}$$

The horsepower producing the circulation is, then,

$$H = \frac{q\,p}{33{,}000} = \frac{28{,}800\times 3}{33{,}000} = 2.61+ \text{ H. P.}$$

Ques. 856.—An airway has a length of 5,000 feet, the perimeter is 32 feet, and the area 60 square feet, what quantity of air will pass at a velocity of 600 feet per minute? Using the Fairley coefficient, what power will be required, the pressure being 9.6 pounds per square foot? *I.—Pa. (B)*

Ans.—The area of the airway being 60 sq. ft., and the velocity of the current 600 ft. per min., the quantity of air passing in the mine is

$$q = a\,v = 60\times 600 = 36{,}000 \text{ cu. ft. per min.}$$

The ventilating pressure being 10 lb. per sq. ft., the power producing the circulation is

$$H = \frac{q\,p}{33{,}000} = \frac{36{,}000\times 9.6}{33{,}000} = 10.472+ \text{ H. P.}$$

Ques. 857.—What power will be required to give a current of 60,000 cubic feet of air per minute in a mine having four equal splits, the airway in each split being 6 ft. × 8 ft. × 5,000 ft.? *M.—Ill.*

Ans.—The total rubbing surface in these four splits is

$$s = 4\,l\,o = 4\times 5{,}000\times 2(6+8) = 560{,}000 \text{ sq. ft.,}$$

and the total area is

$$a = 4(6\times 8) = 192 \text{ sq. ft.}$$

The horsepower required to produce this ventilation is

$$H = \frac{k\,s\,q^3}{33{,}000\times a^3} = \frac{.00000002\times 560{,}000\times 60{,}000^3}{33{,}000\times 192^3} = 10.36+ \text{ H. P.}$$

Ques. 858.—What horsepower of engine is required to ventilate a mine working 300 men, when the water gauge stands at 1 inch? *I.—Ia.*

Ans.—Assuming that 300 miners will require 6 mules, and since the mining laws of Iowa require 100 cu. ft. of air per min. per man, and 500 cu. ft. per min. per mule, the required circulation in this mine is

$$300\times 100+6\times 500 = 33{,}000 \text{ cu. ft. of air per min.}$$

If the water gauge is 1 in., the horsepower of engine required for this ventilation, assuming an efficiency of 60 per cent. for the engine and fan, is calculated as follows:

$$H = \frac{q\,p}{33{,}000} = \frac{33{,}000\times 5.2\times 1}{.60\times 33{,}000} = 8.666+ \text{ H. P.}$$

QUES. 859.—At a mine where the surface elevations of the downcast and furnace shafts are equal, the depth of the downcast is 150 feet, and the dip of the coal seam from the downcast to the furnace shaft $1\frac{1}{2}$ per cent. for a distance of 6,000 feet; the average temperature of the downcast shaft is 40° F., the temperature of the mine 55° F., and the average temperature of the furnace shaft 200° F., find the pressure per square foot and the horsepower that will circulate 90,000 cubic feet of air in this mine. *I.—Pa.* (*B*)

ANS.—This is a case where three temperatures are concerned in producing the circulation in the mine, and as a result beside the two air columns in the upcast and downcast shafts, respectively, there is a third air column existing in the mine on account of the dip of the seam. The vertical height through which this seam falls in passing from the foot of the downcast shaft to the foot of the upcast shaft is $6{,}000 \times .015 = 90$ ft. This is the vertical height of what we may call the dip air column. To find the pressure producing circulation, in pounds per square foot, add together the weights of the two positive air columns (downcast column and dip column) and from their sum subtract the weight of the negative air column (upcast column). Assuming a barometer of 30 in. for the pressure p in this case,

$$p = 1.324 \times 30\left(\frac{150}{460+40} + \frac{90}{460+55} - \frac{150+90}{460+200}\right) = 4.4137+ \text{ lb. per sq. ft.}$$

The horsepower of this circulation is, then,

$$H = \frac{q\,p}{33{,}000} = \frac{90{,}000 \times 4.4137}{33{,}000} = 12.037 \text{ H. P.}$$

RELATION BETWEEN VELOCITY, PRESSURE, AND LENGTH OF AIRWAY

QUES. 860.—In what proportion is the friction of air increased compared with the velocity of the current? *F.—Pa.* (*A*)

ANS.—The friction of air-currents in mines increases as the squares of the velocities; for example, if the velocity is doubled, the friction is increased to four times the original amount.

RELATION BETWEEN VELOCITY AND LENGTH

QUES. 861.—In a certain entry the velocity of the ventilating current is 10 feet per second; what will be the velocity of the aircurrent in another entry of double the length, if the area and the water gauge are the same as in the first entry? *I.—Ia.*

ANS.—In different airways, for the same pressure, the velocity varies as $\sqrt{\frac{a}{l\,o}}$, in which a is the area; l, the length; and o, the perimeter of the airway. In this question, however, the area and, presumably, the perimeter are the same in each entry; and the velocities will therefore vary inversely as the square roots of the lengths of the entries, or as $\sqrt{2} : \sqrt{1}$; hence,

$$x : 10 = \sqrt{1} : \sqrt{2}, \text{ or } x = 10 \div \sqrt{2} = 7.07+ \text{ ft. per sec.}$$

QUES. 862.—To increase the velocity of a current from 5 feet per second to 10 feet per second, how much will it be necessary to increase the ventilating power and what will be the increase in the consumption of coal? *F_1.—Ala.*

ANS.—Increasing the velocity from 5 ft. to 10 ft. per sec. means doubling the volume of air in circulation, and increasing the frictional resistance four times and the power eight times. In other words, the friction developed is as the square, and the power and coal required to accomplish such result, as the cube of the velocity. Practically, it will require the consumption of eight times the coal in the ventilating furnace to double the amount of air, twenty-seven times to treble it, sixty-four times to quadruple it, and so on.

RELATION BETWEEN QUANTITY AND PRESSURE

QUES. 863.—With a water gauge of .25 inch, the velocity of an air-current in a given airway is 200 feet per minute; what water gauge will be required to increase the velocity of the air-current to 400 feet per minute? *I.—Pa. (A)*

ANS.—The ventilating pressure in any given airway varies as the square of the velocity of the current, and the water gauge, in like manner. Hence, letting x represent the required water gauge,

$$x : .25 = 400^2 : 200^2;$$

$$x = \left(\frac{400}{200}\right)^2 \times .25 = 1 \text{ in.};$$

or, expressed in another way, the pressure or water gauge ratio equals the square of the velocity ratio. Then, calling the required water gauge x,

$$\frac{x}{.25} = \left(\frac{400}{200}\right)^2 = 4$$

and

$$x = 4 \times .25 = 1 \text{ in.}$$

QUES. 864.—In order to double the quantity of air in a mine, in what proportion must the ventilating pressure be increased? *F.—Pa. (B)*

ANS.—For the same airway, the pressure varies as the square of the quantity of air in circulation; in other words, the pressure ratio is equal to

the square of the quantity ratio. The quantity ratio in this case being 2, the pressure ratio is equal to $2^2 = 4$. Hence, four times the original pressure will be required to double the quantity of air in circulation in an airway.

QUES. 865.—If it is necessary to double the amount of air in a mine, how much should the pressure and power be increased, respectively? *F_1.—Ala.*

ANS.—In order to double the quantity of air in circulation, it is necessary to have four times the pressure and eight times the power, since the pressure varies as the square of the quantity, and the power as the cube of the quantity of air in any circulation.

QUES. 866.—The water gauge being 1 inch, and the volume of air in circulation 50,000 cubic feet per minute in a certain mine, what will be the volume of air in this mine if the water gauge is increased to 1.6 inches by an increase of power? *F.—Pa. (A)*

ANS.—The quantity of air in circulation, for the same conditions in the airway, is proportional to the square root of the water gauge. Then, calling the required quantity x,

$$\frac{x}{50{,}000} = \sqrt{\frac{1.6}{1}};$$

or, $$x = 50{,}000\sqrt{1.6} = 63{,}245+ \text{ cu. ft. per min.}$$

QUES. 867.—If a water gauge of 1.5 inches produces 95,000 cubic feet of air per minute in a certain mine, what quantity will a water gauge of 2 inches produce, and what horsepower will be developed under the increased water gauge and quantity? *F.—Pa. (B)*

ANS.—For the same conditions in the airway, the quantity of air in circulation is proportional to the square root of the pressure or water gauge producing the circulation. Thus,

$$\sqrt{1.5} : \sqrt{2} = 95{,}000 : x, \text{ or } x = 95{,}000\sqrt{\frac{2}{1.5}} = 109{,}696 \text{ cu. ft. per min.}$$

The power required for the circulation of 109,696 cu. ft. of air against a water gauge of 2 in. is

$$H = \frac{q\,p}{33{,}000} = \frac{109{,}696(5.2 \times 2)}{33{,}000} = 34.570+ \text{ H. P.}$$

QUES. 868.—A fan is making 65 revolutions and producing 35,000 cubic feet of air per minute, against a water gauge of .4 inch; what quantity of air should be produced when the speed of the fan is increased so as to yield a water gauge of .6 inch? *E.—Ill.*

ANS.—In any circulation, the quantity varies as the square root of the water gauge for the same conditions in the airway; the quantity ratio is

equal to the square root of the water-gauge ratio, and calling the required quantity x,

$$\frac{x}{35{,}000} = \sqrt{\frac{.6}{.4}} = \sqrt{1.5};$$

$$x = 35{,}000\sqrt{1.5} = 42{,}866+ \text{ cu. ft. per min.}$$

QUES. 869.—A fan 20 feet in diameter circulates 24,000 cubic feet of air per minute at 60 revolutions and a water gauge of .65 inch; if this quantity is increased to 47,000 cubic feet per minute in the same airway by speeding the fan, what will be the water gauge produced? *M.—B. C., Canada*

ANS.—The pressure or water gauge in an airway is proportional to the square of the quantity of air in circulation; hence, the water-gauge ratio is equal to the square of the quantity ratio, and using the given values and calling the required water gauge x, we have

$$\frac{x}{.65} = \left(\frac{47{,}000}{24{,}000}\right)^2;$$

or, $$x = .65\left(\frac{47}{24}\right)^2 = 2.49+, \text{ say } 2\tfrac{1}{2} \text{ in.}$$

QUES. 870.—If with a water gauge of 2 inches, 150,000 cubic feet of air is circulating, what will be the volume of air if the power is decreased so as to yield a water gauge of 1.64 inches? *F.—Pa. (A)*

ANS.—For the same conditions in the airway, the volume of air in circulation varies as the square root of the pressure, or as the square root of the inches of water gauge. Hence, calling the required volume or quantity x,

$$\sqrt{2} : \sqrt{1.64} = 150{,}000 : x;$$

and $$x = 150{,}000\sqrt{\frac{1.64}{2}} = 135{,}830+ \text{ cu. ft. per min.}$$

RELATION BETWEEN LENGTH OF AIRWAY AND PRESSURE

QUES. 871.—If the airways of a mine are doubled in length, in what proportion would the pressure have to be increased to produce the same volume of air? *F_2.—Ala.*

ANS.—The formula for pressure, in terms of the airway and quantity, is

$$p = \frac{k\,l\,o\,q^2}{a^3}$$

Since in this case k, o, q, and a are constant, the pressure will vary as the length l of the airway. Hence, if the length of the airway be doubled, the pressure must also be doubled to produce the same volume of air.

QUES. 872.—At a certain mine, the water gauge was originally .7 inch; the airways are now three times as long, and the velocity

has increased from 480 to 600 feet per minute; what will be the water-gauge reading under these conditions? *M.—B. C., Canada*

Ans.—The water gauge being proportional to the length of the airway and the square of the velocity,

$$x = .7 \times 3\left(\frac{600}{480}\right)^2 = 3.28 \text{ in.}$$

Ques. 873.—If, with a water gauge of 1 inch, 40,000 cubic feet of air is obtained in an airway 10,000 feet long, what should be the water gauge to circulate the same quantity, when the length of the airway is extended to 20,000 feet, all other things being the same? *F.—Pa. (A)*

Ans.—As stated in answer to the preceding question, the pressure or water gauge increases as the length of the airway. The length of the airway in this case being doubled, the water gauge must also be doubled, making $2 \times 1 = 2$ in.

Ques. 874.—If, after the length of an airway has been doubled, it is also found necessary to double the original quantity of air passing per minute, what pressure per square foot will be required to do this? *M.—Ill.*

Ans.—In this case, in the formula

$$p = \frac{k\,l\,o\,q^2}{a^3},$$

k, o, and a are constant and p varies as $l\,q^2$; then

$$\frac{p}{p} = \frac{l\,q^2}{l\,q^2}$$

or the pressure ratio is equal to the product of the length ratio and the square of the quantity ratio. The length ratio being 2, and the quantity ratio being 2, the pressure ratio is $2 \times 2^2 = 8$. That is to say, it will require eight times the original water gauge to double the quantity of air in circulation when the length of the airway is also doubled.

RELATION BETWEEN LENGTH OF AIRWAY AND VOLUME

Ques. 875.—If the length of an airway is doubled, the ventilating pressure remaining the same, how much will the volume of air in circulation be reduced? *F.—Ia.*

Ans.—For the same ventilating pressure, the quantity varies inversely as the square root of the length of the airway. If the length of the airway is doubled, the pressure remaining the same, the quantity will vary in the ratio $\frac{1}{\sqrt{2}} = .7071$; or the quantity passing in the longer airway will be .7071 times the quantity in the shorter airway.

QUES. 876.—With the same pressure applied, will the same quantity of air pass through an airway 6,000 feet long as through one 4,000 feet long? Why? *F.—Pa. (A)*

ANS.—No. To pass the same quantity of air through airways having the same cross-section but different lengths, requires that the pressure be increased in proportion to the length of the airway. Thus, to pass the same quantity of air through an airway 6,000 feet long as through an airway 4,000 feet long will require $6 \div 4 = 1.5$ times the pressure.

RELATION BETWEEN POWER AND QUANTITY

QUES. 877.—How must the power be increased to maintain a constant current of air in circulation in a mine where the airways are continually increasing in length? *M.—Ill.*

ANS.—The power must be increased in the same proportion as the length of the airways in order to maintain a constant velocity of the air-current unless the air is divided into two or more splits.

QUES. 878.—With 3 horsepower, we are producing 20,000 cubic feet of air per minute; how many horsepower will be required to produce 40,000 cubic feet of air per minute in the same airway? *M.—Ill.*

ANS.—For any given airway, the power producing circulation is proportional to the cube of the quantity, or the power ratio is equal to the cube of the quantity ratio. Calling the power required in this case x,

$$\frac{x}{3} = \left(\frac{40{,}000}{20{,}000}\right)^3 = 2^3 = 8;$$

and $$x = 8 \times 3 = 24 \text{ H. P.}$$

QUES. 879.—If a fan is circulating 57,000 cubic feet of air per minute in a certain airway, with 39 horsepower, what horsepower will be required to increase this quantity to 87,000 cubic feet per minute in the same airway? *M.—B. C., Canada*

ANS.—In mine ventilation, the horsepower on the air is proportional to the cube of the quantity of air in circulation; or, the power ratio is equal to the cube of the quantity ratio; and calling x the required horsepower, we have, in this case,

$$\frac{x}{39} = \left(\frac{87{,}000}{57{,}000}\right)^3;$$

or $$x = 39\left(\frac{87}{57}\right)^3 = 138.6+ \text{ H. P.}$$

QUES. 880.—How much has the ventilating power to be increased to treble the quantity of air in any given circulation? *F.—Pa. (A)*

ANS.—For any given circulation, the power varies as the cube of the velocity or quantity of air. To treble the quantity of air in any given airway will require $3^3 = 27$ times the original power producing circulation in the airway.

QUES. 881.—If 42,000 units of work produce a current of 31,500 cubic feet of air in a mine, how many units of work will be required to circulate 70,000 cubic feet of air in the same mine? *I.—Ia.*

ANS.—Since, in any circulation, the power or work producing the current varies as the cube of the quantity or air in circulation,

$$31{,}500^3 : 70{,}000^3 = 42{,}000 : x;$$

or

$$x = 42{,}000 \times \left(\frac{70{,}000}{31{,}500}\right)^3 = 42{,}000\left(\frac{20}{9}\right)^3 = 42{,}000 \times 10.974$$
$$= 460{,}908 \text{ units of work}$$

QUES. 882.—If 27 horsepower produce 45,000 cubic feet of air per minute in a certain mine, what quantity will be produced if the power is increased to 35.937 horsepower? *F.—Pa. (A)*

ANS.—For the same mine or airway, the quantity of air in circulation varies as the cube root of the power producing the circulation, or the quantity ratio is equal to the power ratio; and, calling the required quantity x, we have

$$\frac{x}{45{,}000} = \sqrt[3]{\frac{35.937}{27}} = \sqrt[3]{1.331} = 1.1;$$
$$x = 45{,}000 \times 1.1 = 49{,}500 \text{ cu. ft. per min.}$$

QUES. 883.—What horsepower will be expended in circulating 20,000 cubic feet of air against a mine pressure of 1.75 pounds per square foot? If the quantity is increased to 30,000 cubic feet, what will be the horsepower? *F.—Pa. (A)*

ANS.—For the horsepower, in this case, we have

$$H = \frac{p\,q}{33{,}000} = \frac{1.75 \times 20{,}000}{33{,}000} = 1.06+ \text{ H. P.}$$

In any given circulation the power varies as the cube of the quantity, or the ratio of power is equal to the cube of the ratio of quantity; and, calling the required horsepower x,

$$\frac{x}{1.06} = \left(\frac{30{,}000}{20{,}000}\right)^3 = \left(\frac{3}{2}\right)^3 = 1.5^3;$$

and

$$x = 1.06 \times 1.5^3 = 3.577+ \text{ H. P.}$$

CHAPTER VIII

COMPARISON OF AIRWAYS

BEST FORM OF AIRWAY

QUES. 900.—What form of airway will give the most air with the same power, and why? *F_1.—Ala.*

ANS.—For the same area and length the circular form of airway will yield the largest quantity of air, with the same power, because the ratio of the sectional area to the rubbing surface is greater, in this form, than in any other. The square form of airway presents the next greater ratio of sectional area to rubbing surface, while any rectangular or trapezoidal form of airway presents a less ratio and is, therefore, the form of airway least calculated to pass a large quantity of air under a small expenditure of power.

QUES. 901.—How does the shape of an airway affect the ventilation of a mine? *I.—Pa. (B)*

ANS.—The shape of the airway affects the circulation due to any given power, by changing the relation between the sectional area and the rubbing

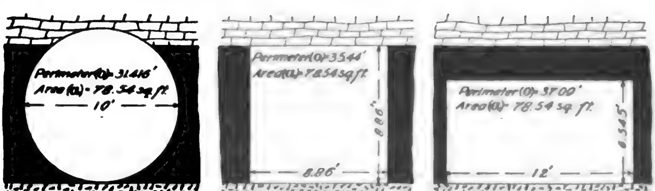


FIG. 1

surface of the airway. For the same power the quantity of air in circulation varies as $\left(\frac{a}{\sqrt[3]{k\,s}}\right)$. (This expression is sometimes called the relative potential of the airway, and is very useful in comparing airways.) For airways of equal area and length, the quantity of air circulated by a given power varies as $\left(\frac{1}{\sqrt[3]{o}}\right)$. Fig. 1 shows three common forms of airways of equal area, the first being a circle 10 ft. in diameter, the second a square, and the third a rectangle 12 ft. wide, each of these having the same area, 78.54

sq. ft. The perimeter o is given in the figure, for each airway, and substituting these values for o, in the expression $\frac{a}{\sqrt[3]{k\,s}}$, the relative quantities that the same power will pass in these three forms of airways, having the same sectional area and length are as follows:

Circular airway, $\frac{1}{\sqrt[3]{31.416}} = .31692$

Square airway, $\frac{1}{\sqrt[3]{35.44}} = .30444$

Rectangular airway, $\frac{1}{\sqrt[3]{37.09}} = .29985$

That is to say, the same power will pass 31,692 cu. ft. of air in a circular airway, 30,444 cu. ft. in a square airway, and 29,985 cu. ft. in a rectangular airway having a width of about twice its height, when all the airways have the same area and length.

QUES. 902.—What form of airway gives the best results, and why? *F_1.—Ala.*

ANS.—The typical forms of airways are the circular, square, rectangular, and trapezoidal. For the same area, the circular form of airway will yield the largest quantity of air, with the same power; because for this cross-section the expression $\frac{a}{\sqrt[3]{k\,s}}$ is greater than for the other forms.

RELATIVE QUANTITIES OF AIR PASSING THROUGH AIRWAYS OF DIFFERENT FORMS

QUES. 903.—Find the number of square feet of rubbing surface in the following airways: 4 feet high, 9 feet wide, and 6,000 feet long; 6 feet high, 6 feet wide, and 6,500 feet long. With the same power used in each, what difference will there be in the quantity of air passing? Give reasons. *F.—Pa. (B)*

ANS.—The rubbing surface of the first airway is

$$2(4+9)\times 6{,}000 = 156{,}000 \text{ sq. ft.}$$

The area is $4\times 9 = 36$ sq. ft.

The rubbing surface of the second airway is

$$2(6+6)\times 6{,}500 = 156{,}000 \text{ sq. ft.}$$

The area is $6\times 6 = 36$ sq. ft.

The formula for the quantity of air, in terms of the power, area, and rubbing surface, is

$$q = a\sqrt[3]{\frac{u}{k\,s}}$$

The same power applied to each of these airways, therefore, will produce the same quantity of air, because the area and rubbing surface are the same in each case.

QUES. 904.—If 40,000 cubic feet of air passes each minute through an airway 6 ft. × 8 ft. in section, while the water gauge is 1.2 inches, what quantity will pass per minute through an airway of the same length, 8 ft. × 12 ft. in section, when the power producing the ventilation is the same? *I.—Ia.*

ANS.—When the power remains the same, the quantity of air in circulation varies as the expression

$$\frac{a}{\sqrt[3]{l\,o}}$$

in which
a = area of airway, in square feet;
l = length of airway, in feet;
o = perimeter of airway, in feet.

In the present case, the length of the airways being the same, the quantity varies as the expression $\frac{a}{\sqrt[3]{o}}$. Then, if the required quantity is represented by x,

$$\frac{x}{40{,}000} = \frac{8\times 12}{\sqrt[3]{2(8+12)}} \div \frac{6\times 8}{\sqrt[3]{2(6+8)}};$$

or,
$$x = 40{,}000\times\frac{8\times 12}{6\times 8}\times\sqrt[3]{\frac{2(6+8)}{2(8+12)}}$$

Canceling the common factors and simplifying,

$$x = 40{,}000\times 2\times\sqrt[3]{\frac{7}{10}} = 80{,}000\times .8879 = 71{,}032 \text{ cu. ft.}$$

QUES. 905.—If 28,000 cubic feet of air per minute passes through an airway 6 ft. × 7 ft., how much air will pass through an airway 5 ft. × 5 ft. of the same length, the power remaining the same? *M.—B. C., Canada*

ANS.—The formula expressing the power required to circulate a given quantity of air in a given airway is

$$u = \frac{k\,l\,o\,q^3}{a^3}$$

In this case, u, k, and l being constant, q varies as $\frac{a}{\sqrt[3]{o}}$ for each airway.

Calling x the required quantity, and substituting the given values,

$$\frac{x}{28{,}000} = \frac{5\times 5}{\sqrt[3]{2(5+5)}} \div \frac{6\times 7}{\sqrt[3]{2(6+7)}};$$

or,
$$x = 28{,}000\,\frac{25}{42}\sqrt[3]{\frac{13}{10}} = 18{,}190+ \text{ cu. ft. per min.}$$

QUES. 906.—Which would you consider the better, two return airways of 5 ft. × 5 ft., or one return airway 8 ft. × 6.25 ft.? *M.—Ill.*

ANS.—For the purpose of ventilation, the airway that will pass a given quantity of air with the least power is the better airway. The horsepower of any given circulation expressed in terms of the airway is given by the formula

$$H = \frac{k\,l\,o\,q^3}{33{,}000\,a^3}$$

For airways of the same length passing the same quantity of air, the power varies as the expression $\frac{o}{a^3}$, and calculating the value of this expression for each case given,

Two airways, each 5 ft. × 5 ft.,

$$\frac{o}{a^3} = \frac{2\times2(5+5)}{(2\times5\times5)^3} = \frac{40}{50^3}$$

One airway, 8 ft. × 6.25 ft.,

$$\frac{o}{a^3} = \frac{2(8+6.25)}{(8\times6.25)^3} = \frac{28.5}{50^3}$$

Expressing the horsepower of the circulation in two airways by H_2 and that in one airway by H_1,

$$\frac{H_1}{H_1} = \frac{28.5}{50^3} \div \frac{40}{50^3} = \frac{28.5}{50^3} \times \frac{50^3}{40} = \frac{28.5}{40}$$

Hence, the length of all the airways being equal, 28.5 H. P. applied to the single airway will produce the same circulation that 40 H. P. will produce in the two airways.

QUES. 907.—If you had your choice of the following intake airways, one airway 10 ft. × 10 ft., one airway 5 ft. × 20 ft., or two airways each 5 ft. × 10 ft., which would you prefer, and why? *F.—Pa. (A)*

ANS.—The airway that will pass the largest quantity of air with the same power is preferable. Assuming the length to be the same for all the airways, the quantity of air circulated by the same power will vary as the expression $\frac{a}{\sqrt[3]{o}}$, in which a is the area, in square feet, and o the perimeter, in feet, of any airway. Substituting the given values, we have for the relative quantities of air in circulation,

A, one airway (10 × 10),

$$\frac{a}{\sqrt[3]{o}} = \frac{10 \times 10}{\sqrt[3]{2(10+10)}} = \frac{100}{\sqrt[3]{40}} = 29.240$$

B, one airway (5 × 20),

$$\frac{a}{\sqrt[3]{o}} = \frac{5\times20}{\sqrt[3]{2(5+20)}} = \frac{100}{\sqrt[3]{50}} = 27.144$$

C, two airways (5 × 10),

$$\frac{a}{\sqrt[3]{o}} = \frac{2(5\times10)}{\sqrt[3]{2\times2(5+10)}} = \frac{100}{\sqrt[3]{60}} = 25.543$$

That is to say, the same power will pass 29,240 cu. ft. in *A*, 27,144 cu. ft. in *B*, and 25,543 cu. ft. in *C*. The first of these airways will therefore give

the largest quantity of air for the same power, and for this reason is the one to be preferred.

QUES. 908.—Calculate the area and perimeter of four airways, each 4 ft. × 4 ft.; one airway 8 ft. × 8 ft. The power being the same in each case, state whether the former or latter will allow the greater quantity of air to pass. *F_1.—Ala.*

ANS.—The total area of four airways, each 4 ft. × 4 ft. in section, is $4(4\times4) = 64$ sq. ft. and the total perimeter of these four airways is also $4(4\times4) = 64$ lin. ft. The area of one airway 8 ft. × 8 ft. in section is $8\times8 = 64$ sq. ft., but the perimeter is only $4\times8 = 32$ ft. With a given power, more air will pass through the 8×8 airway, because it has less rubbing surface than the other four airways together, in fact, just one-half, and therefore it will have less frictional resistance, which will enable it to pass more air.

QUES. 909.—(*a*) How many airways 4 feet square will equal in area one airway 8 feet square? Which will pass the greater quantity of air, and why, the pressure per square foot of area being the same in each case? (*b*) Assuming another square airway to have a rubbing surface of 84,000 square feet and a length of 3,000 feet, the quantity of air passing being 44,100 cubic feet per minute, what is the velocity of the air-current? *E.—Pa. (B)*

ANS.—(*a*) $$\frac{8\times8}{4\times4} = 4 \text{ airways 4 ft. square}$$

For a constant pressure and an equal length of airway, the quantity of air passing in each split is proportional to $\sqrt{\frac{a^3}{o}}$ for that split. The total areas and perimeters of the airways are, four airways 4 ft. × 4 ft., $a = 4(4\times4) = 64$ sq. ft., $o = 4(4\times4) = 64$ ft.; one airway 8 ft. × 8 ft., $a = 8\times8 = 64$ sq. ft., $o = 4\times8 = 32$ ft. Now, assume 10,000 cu. ft. of air passing in the four airways 4 ft. × 4 ft., and let x be the quantity passing in one airway 8 ft. × 8 ft., under the same pressure per square foot, then

$$\frac{x}{10{,}000} = \sqrt{\frac{64^3}{32}} \div \sqrt{\frac{64^3}{64}};$$

or, $$\frac{x}{10{,}000} = \sqrt{\frac{64^3}{32}\times\frac{64}{64^3}} = \sqrt{2} = 1.4142+;$$

and $$x = 10{,}000\times1.4142 = 14{,}142 \text{ cu. ft. per min.}$$

That is to say, for every 10,000 cu. ft. of air passing in the four airways, 4 ft. × 4 ft., there will be 14,142 cu. ft. passing in the single airway 8 ft. × 8 ft., under the same pressure, all the airways being of equal length.

(*b*) The area of this airway is

$$\left(\frac{84{,}000}{4\times3{,}000}\right)^2 = 49 \text{ sq. ft.}$$

and the velocity of the current is then

$$44{,}100\div49 = 900 \text{ ft. per min.}$$

QUES. 910.—If 10,000 cubic feet of air per minute will pass in an airway 6 ft. × 6 ft., 1,000 yards long, what amount will pass in two airways, each 3 ft. × 6 ft., of the same length and with the same ventilating pressure? *M.—B. C., Canada*

ANS.—For the same pressure, the quantity of air in circulation is proportional to $a\sqrt{\frac{a}{l\,o}}$; or, in this case, since the length of the airways are the same, the relative potential is $a\sqrt{\frac{a}{o}}$. The total areas and perimeters in each case are, one airway 6 ft. × 6 ft., $a = 6\times6 = 36$ sq. ft., $o = 4\times6 = 24$ ft.; two airways 3 ft. × 6 ft., $a = 2(3\times6) = 36$ sq. ft., $o = 2\times2(3+6) = 36$ ft. Then, substituting these values,

$$36\sqrt{\frac{36}{24}} : 2\left(18\sqrt{\frac{18}{18}}\right) = 10{,}000 : x;$$

or,
$$x = 10{,}000\times\frac{36}{36}\sqrt{\frac{24}{36}} = 8{,}165 \text{ cu. ft. per min.}$$

QUES. 911.—With the same pressure applied and the same distance to be traversed, which will pass the larger quantity of air, three airways 4 ft. × 6 ft., or one airway 8 ft. × 9 ft.? Why? *F.—Pa. (A)*

ANS.—The total areas and perimeters in each case are, three airways each 4 ft. × 6 ft., $a = 3(4\times6) = 72$ sq. ft., $o = 3\times2(4+6) = 60$ ft.; one airway 8 ft. × 9 ft., $a = 8\times9 = 72$ sq. ft., $o = 2(8+9) = 34$ ft. For the same pressure and the same length of airway, the quantity of air circulating in any airway varies as the relative potential $a\sqrt{\frac{a}{o}}$; calling the quantity of air passing in the three airways q_3, and that in one airway q_1,

$$\frac{q_3}{q_1} = 72\sqrt{\frac{72}{60}} \div 72\sqrt{\frac{72}{34}};$$

or,
$$\frac{q_3}{q_1} = \frac{72}{72}\sqrt{\frac{72}{60}\times\frac{34}{72}} = \sqrt{\frac{17}{30}} = .7527;$$

$$\frac{q_3}{q_1} = \frac{.7527}{1} = \frac{7{,}527}{10{,}000}$$

That is to say, the same pressure that will pass 7,527 cu. ft. of air per min., in three airways 4 ft. × 6 ft., will pass 10,000 cu. ft. per min. in a single airway 8 ft. × 9 ft., the lengths of all the airways being equal.

QUES. 912.—There are two airways of equal length, one 4 ft. × 4 ft., the other 6 ft. × 6 ft.; the ventilating pressure being the same in each case, will the velocity of air be the same in each airway; and if not, what will be the cause of the difference? *F.—Pa. (B)*

Ans.—The expression for the unit of ventilating pressure is

$$p = \frac{k\,l\,o\,v^2}{a} \qquad (1)$$

in which p = unit of ventilating pressure, in pounds per square foot;
k = unit resistance, in pounds;
l = length of airway, in feet;
o = perimeter of airway, in feet;
a = sectional area of airway, in square feet;
v = velocity of air-current, in feet per minute.

When comparing airways of equal length under equal pressure, p, k, and l are constant, and we may write

$$\frac{o_1 v_1^2}{a_1} = \frac{o_2 v_2^2}{a_2} \qquad (2)$$

Calling the velocity of the air in the $4' \times 4'$ airway 1, and the velocity in the $6' \times 6'$ airway x, and substituting the given values in equation **2**,

$$\frac{2(4+4)1^2}{4\times 4} = \frac{2(6+6)x^2}{6\times 6};$$

and
$$x = \sqrt{\frac{2(4+4)}{2(6+6)} \times \frac{6\times 6}{4\times 4}} = \frac{3}{2}\sqrt{\frac{2}{3}} = 1.225$$

This shows that for an equal pressure the velocity of the air-current in the $6' \times 6'$ airway will be 1.225 times that in the $4' \times 4'$ airway.

Ques. 913.—An airway 600 yards long and 6 ft. × 6 ft. in section, passes 3,000 cubic feet per minute under a given ventilating pressure; what quantity will the same pressure circulate in another airway 700 yards long, and 5 ft. × 8 ft. in section?

M.—B. C., Canada

Ans.—The formula expressing the unit of ventilating pressure in terms of the airway and the quantity of air in circulation is

$$p = \frac{k\,l\,o\,q^2}{a^3}$$

In this case, p and k being constant, q varies as the relative potential $a\sqrt{\frac{a}{l\,o}}$ for each airway. Since the quantity varies as the relative potential, the quantity ratio is equal to the relative-potential ratio, and substituting the given values and calling the required quantity x,

$$\frac{x}{3{,}000} = 40\sqrt{\frac{40}{(3\times 700)\times 2(5+8)}} \div 36\sqrt{\frac{36}{(3\times 600)\times 2(6+6)}};$$

or,
$$\frac{x}{3{,}000} = \frac{40}{36}\sqrt{\frac{40}{36} \times \frac{(3\times 600)\times 2(6+6)}{(3\times 700)\times 2(5+8)}};$$

and, by cancelation,

$$x = 3{,}000 \times \frac{10}{9}\sqrt{\frac{10}{9} \times \frac{6}{7} \times \frac{12}{13}} = 3{,}125+ \text{ cu. ft. per min.}$$

Ques. 914.—If 2 horsepower produce 10,000 cubic feet of air per minute in an airway 10 ft. × 10 ft., how many horsepower will it take to produce the same amount in an airway 10 ft. × 7.5 ft.?
M.—Ill.

Ans.—The formula for power in terms of the airway and quantity is

$$u = \frac{k\,l\,o\,q^3}{a^3};$$

therefore, for the two airways,

$$\frac{u_1}{u_2} = \frac{k\,l_1\,o_1\,q_1^3}{a_1^3} \div \frac{k\,l_2\,o_2\,q_2^3}{a_2^3}$$

Assuming the airways to have the same length, k, l, and q are the same in each case; hence, u varies as $\frac{o}{a^3}$; and

$$\frac{u_1}{u_2} = \frac{\frac{o_1}{a_1^3}}{\frac{o_2}{a_2^3}} = \frac{o_1}{o_2} \times \left(\frac{a_2}{a_1}\right)^3;$$

$u_1 = x$; $\qquad u_2 = 2$;
$o_1 = 2(10+7.5)$; $\qquad a_1 = 10 \times 7.5$;
$o_2 = 2(10+10)$; $\qquad a_2 = 10 \times 10$;

then, $$\frac{x}{2} = \frac{2(10+7.5)}{2(10+10)} \times \left(\frac{10 \times 10}{10 \times 7.5}\right)^3;$$

and $$x = 2\left(\frac{17.5}{20}\right)\left(\frac{100}{75}\right)^3 = 1.75\left(\frac{4}{3}\right)^3 = 4.148 \text{ H. P.}$$

Ques. 915.—Which of two airways, of the same length, one being 8 ft. × 8 ft. in section, and the other 4 ft. × 16 ft. in section, will pass the greater quantity of air under the same pressure? Give the reason for your answer. *M.—Ill.*

Ans.—In this case, the sectional areas of the airways are equal, since $8 \times 8 = 64$, and $4 \times 16 = 64$. The perimeters of the sections are not, however, equal, for $2(8+8) = 32$ and $2(4+16) = 40$. The first of these two airways will, therefore, pass the greater quantity, because its perimeter or rubbing surface is less than that of the second, and the quantity varies inversely as the square root of the rubbing surface, when the pressure remains constant. For example, suppose that 50,000 cu. ft. of air per min. is passing in the 8 ft. × 8 ft. airway and letting x equal the quantity passing in the 4 ft. × 16 ft. airway, then, if the pressure is the same for each airway, we have, writing the perimeters for the rubbing surfaces, since the lengths are equal,

$$\sqrt{32} : \sqrt{40} = x : 50{,}000;$$

or, $$x = \frac{\sqrt{32}}{\sqrt{40}} \times 50{,}000 = \sqrt{\frac{32}{40}} \times 50{,}000 = \sqrt{.8} \times 50{,}000 = 44{,}721 \text{ cu. ft.}$$

QUES. 916.—If 40,000 cubic feet of air per minute passes through an airway 9 ft. × 6 ft., what is the length of one side of a square airway through which 70,000 cubic feet per minute will pass, the pressure remaining the same? *I.—Pa. (B)*

ANS.—The equation expressing the pressure producing circulation is

$$p = \frac{k\,l\,o\,q^2}{a^3};$$

in this case, the pressure and length of the airways being constant, the expression $\frac{o\,q^2}{a^3}$ is the same for both airways, that is,

$$\frac{o_1\,q_1^2}{a_1^3} = \frac{o_2\,q_2^2}{a_2^3};$$

calling one side of the square d, $o_1 = 2(9+6)$; $q_1 = 40{,}000$; $a_1 = 9 \times 6$; $o_2 = 4\,d$; $q_2 = 70{,}000$; $a_2 = d^2$; and substituting these values,

$$\frac{2(9+6)\times 4^2}{(9\times 6)^3} = \frac{4\,d \times 7^2}{(d \times d)^3} = \frac{4 \times 49}{d^5};$$

whence $$d = \sqrt[5]{\frac{54^3 \times 4 \times 49}{30 \times 16}} = 9.155 \text{ ft.}$$

QUES. 917.—The airways of a mine were 1 mile long, and the water gauge was .7 inch; the length of the airways being now increased four times, and the velocity being also increased from 500 to 700 feet per minute, what is the water gauge? *I.—Pa. (B)*

ANS.—The formula for pressure in terms of the airway and the velocity is

$$p = \frac{k\,l\,o\,v^2}{a}$$

If the area and perimeter of the airway remain constant, the pressure or water gauge is proportional to the length and the square of the velocity; that is,

$$\frac{p_1}{p_2} = \frac{l_1\,v_1^2}{l_2\,v_2^2};$$

hence, the water-gauge ratio is equal to the product of the length ratio and the square of the velocity ratio. Calling the second water gauge x, the first water gauge being .7, the water-gauge ratio is $\frac{x}{.7}$; and in like manner the corresponding length ratio is $\frac{4}{1}$, and the velocity ratio, $\frac{700}{500} = \frac{7}{5}$, then

$$\frac{x}{.7} = 4 \times \left(\frac{7}{5}\right)^2;$$

or, $$x = .7 \times 4 \times \frac{49}{25} = 5.49 \text{ in.}$$

QUES. 918.—A mine has three airways, 6 ft. × 6 ft., 6 ft. × 7 ft., and 6 ft. × 8 ft., respectively; what will be their relative lengths

in order to pass equal quantities, all of them being subject to the same ventilating pressure? *M.—B. C., Canada*

ANS.—The formula for the ventilating pressure is

$$p = \frac{k\,l\,o\,q^2}{a^3};$$

transposing the formula,

$$l = \frac{p\,a^3}{k\,o\,q^2};$$

since by the conditions of the problem p, k, and q are the same for each airway, l varies directly as $\frac{a^3}{o}$. This expression for each airway, therefore, gives the relative length of each airway that will pass the same quantity of air under the same pressure. Substituting the given values,

First airway, $\frac{a^3}{o} = \frac{(6\times 6)^3}{2(6+6)} = 1{,}944$ ft.

Second airway, $\frac{a^3}{o} = \frac{(6\times 7)^3}{2(6+7)} = 2{,}849.5$ ft.

Third airway, $\frac{a^3}{o} = \frac{(6\times 8)^3}{2(6+8)} = 3{,}949.7$ ft.

QUES. 919.—If 36,000 cubic feet of air is passing through an airway 6 ft. × 10 ft., under a pressure of 3.6 pounds per square foot, what pressure is necessary in an airway 5 ft. × 10 ft. to pass the same quantity? *I.—Pa. (B)*

ANS.—In the first airway, the area is $6\times 10 = 60$ sq. ft., and the perimeter $2(6+10) = 32$ ft.; in the second airway, the area is $5\times 10 = 50$ sq. ft., and the perimeter $2(5+10) = 30$ ft.

$$\frac{p_1^2}{p_2} = \frac{k_1\,l_1\,o_1\,q_1^2}{a_1^3} \div \frac{k\,l_2\,o_2\,q_2^2}{a_2^3}$$

Assuming the length of the two airways to be equal and the quantity being the same in each,

$$\frac{p_1}{p_2} = \frac{o_1}{a_1^3} \div \frac{o_2}{a_2^3};$$

$$\frac{p_1}{p_2} = \frac{o_1}{o_2} \times \left(\frac{a_2}{a_1}\right)^3;$$

that is, the pressure varies as the perimeter, and inversely as the cube of the area; hence, the pressure ratio is equal to the product of the perimeter ratio and the cube of the inverse area ratio. Calling the required pressure in the second airway x, the pressure in the first airway being 3.6, the pressure ratio is $\frac{x}{3.6}$; then,

$$\frac{x}{3.6} = \frac{30}{32} \times \left(\frac{60}{50}\right)^3 = \frac{15}{16}\left(\frac{6}{5}\right)^3;$$

and $$x = 3.6 \times \frac{15}{16} \times 1.2^3 = 5.8+ \text{ lb. per sq. ft.}$$

SIMILAR AIRWAYS

QUES. 920.—If 40,000 cubic feet of air per minute passes through an airway 6 ft. × 6 ft. sectional area, with a water gauge of 1.4 inches, what quantity of air will pass through another airway of the same length, 8 ft. × 8 ft. in section, when the pressure is the same? *I.—Ia.*

ANS.—The pressure and length of the airways being the same in each case, the quantity of air in circulation varies as $a\sqrt{\frac{a}{o}}$; calling the required quantity x,

$$\frac{x}{40,000} = 64\sqrt{\frac{64}{32}} \div 36\sqrt{\frac{36}{24}};$$

or,

$$\frac{x}{40,000} = \frac{64}{36}\sqrt{\frac{64}{32}\times\frac{24}{36}} = \frac{16}{9}\sqrt{\frac{4}{3}};$$

and

$$x = 40,000\times\frac{16}{9}\sqrt{\frac{4}{3}} = 82,112 \text{ cu. ft. per min.}$$

Since these airways are similar, we may apply the law that in similar airways for a constant pressure the quantity of air in circulation will vary as the square root of the fifth power of the similar sides. Calling the required quantity x,

$$\frac{x}{40,000} = \sqrt{\left(\frac{8}{6}\right)^5};$$

and

$$x = 40,000\times\sqrt{\left(\frac{8}{6}\right)^5} = 82,112 \text{ cu. ft. per min.}$$

QUES. 921.—Which will pass the greater quantity of air, and why; one airway 8 ft. × 8 ft., or four airways 4 ft. × 4 ft., the pressure being the same in each case and all the airways of equal length? *B.—B. C., Canada*

ANS.—The airways in this case are similar and for a constant pressure the quantity of air in circulation is proportional to the square root of the fifth power of the similar sides; or the quantity ratio is equal to the square root of the fifth power of the ratio of the similar sides. Calling the quantity of air passing in the 8 ft.×8 ft. airway q_1, and that in one 4 ft.×4 ft. airway q_2, we have

$$\frac{q_1}{q_2} = \sqrt{\left(\frac{8}{4}\right)^5} = \sqrt{2^5} = \sqrt{32} = 5.656+$$

Or, calling the quantity of air passing in one 4 ft.×4 ft. airway 1, the quantity passing in the 8 ft.×8 ft. airway is 5.656. Then, the pressure remaining constant, for every 5,656 cu. ft. of air passing in one airway 8 ft. × 8 ft., there will be 4,000 cu. ft. of air passing in four airways each 4 ft.×4 ft., all the airways being of the same length.

QUES. 922.—If 20,000 cubic feet of air per minute passes through a circular airway 10 feet in diameter, how many cubic feet per minute will pass through a similar airway 6 feet in diameter, the length and pressure remaining the same? *I.—Pa.* (*B*)

ANS.—For circular airways of equal length, the quantity of air circulated by the same pressure is proportional to the square root of the fifth power of the diameter; or the square of the quantity ratio is equal to the fifth power of the diameter ratio. Calling the required quantity of air in the second airway x, the quantity in the first airway being 20,000 cu. ft. per min., the quantity ratio is $\frac{x}{20{,}000}$, and the corresponding diameter ratio $\frac{6}{10} = \frac{3}{5}$; hence,

$$\left(\frac{x}{20{,}000}\right)^2 = \left(\frac{3}{5}\right)^5 = .6^5,$$

and

$$x = 20{,}000\sqrt{.6^5} = 5{,}577+ \text{ cu. ft. per min.}$$

QUES. 923.—An airway 7,000 feet long, 6 feet high, and 8 feet wide, passes 20,000 cubic feet of air per minute. It is desired to enlarge the airway in the same rectangular form to pass 60,000 cubic feet of air per minute, the pressure remaining the same. What are the dimensions of the enlarged airway? *I.—Pa.* (*B*)

ANS.—Making the form of the new airway similar in cross-section to that of the old one, the width of the new airway is

$$x = 8\sqrt[5]{\left(\frac{60{,}000}{20{,}000}\right)^2} = 8\sqrt[5]{9} = 12.42 \text{ ft.}$$

The height of the new airway will then be

$$12.42 \times \frac{6}{8} = 9.32 \text{ ft.}$$

The rule for similar airways is, for the same pressure, the fifth power of similar sides varies as the square of the circulation.

QUES. 924.—If an airway measuring 7 ft. × 7 ft. has 30,000 cubic feet of air passing per minute, what should be the dimensions of a square airway to pass 55,000 cubic feet of air per minute, with the same pressure? *I.—Pa.* (*A*)

ANS.—The airways being similar and under the same pressure, the fifth power of the ratio of similar sides is equal to the square of the quantity ratio; or, calling one side of the required square airway x,

$$\left(\frac{x}{7}\right)^5 = \left(\frac{55{,}000}{30{,}000}\right)^2 = \left(\frac{11}{6}\right)^2,$$

and

$$x = 7\sqrt[5]{\frac{121}{36}} = 8.92+ \text{ ft.}$$

RELATIVE SIZES OF UPCAST AND DOWNCAST SHAFTS

QUES. 925.—Which do you consider should be the larger, the upcast or the downcast shaft, and why? *F.—Ia.*

ANS.—The upcast shaft of a mine should always have a larger sectional area than the downcast shaft, for the reason that under the conditions of mining the return current almost invariably has a larger volume than that of the intake. The volume of the return current is increased in the following ways: (1) By the gases that are produced constantly in the mine workings and in the waste or abandoned places in the mine. (2) During a large portion of the year, especially in the winter season, the temperature of the return current is greater than that of the intake; as a result of this higher temperature the volume of the return air is greater than that of the intake current. (3) The return air of any circulation, whether exhausting or blowing, is always subject to a less pressure than the intake air, and as a consequence its volume is thereby slightly increased. This increase of area for the upcast shaft should be determined according to the gaseous condition of the mine in connection with the increased temperature of the upcast current.

QUES. 926.—Which, if either, should be the larger, the main intake or return airways, and why? *I.—Pa. (B)*

ANS.—The main return airways should always be the larger of the two for several reasons: (1) The return air-current during the greater portion of the year has a higher temperature than that of the intake current, and as a consequence is of greater volume. (2) The return current is usually increased in volume by the addition of mine gases, of which at times there is a considerable volume. (3) Owing to the mine resistance, the intake current is under a greater pressure than the return current, and on this account also the volume of the return current is always slightly increased.

QUES. 927.—What effect will timber in a roadway have in the ventilation of a mine, and in what part of the airway will it last the longest, and why? *F.—Pa. (B)*

ANS.—The effect of timber, as regards ventilation, is to reduce the sectional area of the airway and increase its resistance, thereby decreasing the quantity of air in circulation, the ventilating power remaining constant. In general, timber will last longer in the intake airway of a mine than in the return. There are several causes producing the decay of mine timber, and these vary according to conditions. Although the return air-current in a mine approaches saturation more or less closely, the air holds its moisture and for this reason the return air-course is generally dry and the timber therein subject to dry rot, which induces a more rapid decay perhaps than any other cause. An alternate dry and wet condition of the workings, often found where the ventilation is slack and the mine damp, induces a fungus growth that destroys timber rapidly.

CHAPTER IX

SPLITTING AIR-CURRENTS

DEFINITION OF SPLITTING

QUES. 950.—What is meant by splitting the air-current? *F.—Pa.* (*A*)

ANS.—The term ***splitting***, in ventilation, relates to the division of the air-current into two or more splits or currents. The term ***split*** is synonymous with division. A split of the main current is called a ***primary split;*** a split of a primary split is called a ***secondary split;*** a split of a secondary split is called a ***tertiary split.***

QUES. 951.—What is meant by splitting the air volume, and what advantages are to be derived therefrom? *F.—Pa.* (*B*)

ANS.—By splitting is meant dividing the main air-current entering the mine into two or more splits or currents. This may be done at the foot of the downcast shaft or at different points in the mine as required. The advantages of splitting are as follows: (1) A larger amount of air is circulated by the same power. (2) The entire circulation of the mine is divided into districts, each having its own intake and return, and is thereby more easily controlled. (3) Purer air is supplied to the working face, since the return from each district is conducted directly to the main return instead of passing along the entire working face. (4) In case of an explosion occurring in one district, the effect is not as often communicated to other parts of the mine. (5) A large volume of air is conducted through the mine workings at a normal velocity, thereby reducing the danger arising from high velocities of the air in gaseous workings.

EFFECT OF SPLITTING AN AIR-CURRENT

QUES. 952.—What, in your judgment, is the best means of reducing the friction of air in mines? *F.—Pa.* (*A*)

ANS.—The friction of air in mines is reduced by reducing the lengths of the airways to a minimum, and increasing their sectional area as much as

possible by splitting the air-currents wherever this can be done, thus making it possible to circulate the same quantity of air with less power.

QUES. 953.—Is it good practice to split the air-current in a mine? *I.—Ia.*

ANS.—When the air-current is traveling at a high velocity, it is good practice to divide this current into splits when this can be accomplished at a reasonable expense. An air-current should always be split at the mouth of a pair of cross-entries, or at any point in the mine where the entries penetrate separate sections of the workings, if the development and need in these sections will warrant the expense. The matter of splitting the air-current is largely a question of velocity, since in practice this is reduced each time the current is divided.

QUES. 954.—Is it good practice to split the air-current? Why? *F.—Pa. (A)*

ANS.—Yes, within certain reasonable limits, because the power applied to the air at the mouths of the splits remaining the same, the quantity of air in circulation is increased in proportion to the number of splits.

QUES. 955.—What are the important factors necessary to insure good ventilation at the face of the mine and not get too high a water gauge, provided that the quantity entering the mine is fully adequate? *F.—Pa. (B)*

ANS.—The ventilation of the working face under these conditions is made more efficient and satisfactory when the current is divided into splits. A larger quantity of air is circulated with the same power. Purer air is supplied directly to the working face, and the return current laden with smoke and gas from one section of the mine is not required to pass through another section, but is conducted directly to the main return current. Greater safety is also obtained in the splitting of the air, since an explosion occurring in one section of the mine is more often confined to that section, instead of being transmitted to the other working places in the mine.

QUES. 956.—If there is 60,000 cubic feet of air passing in a single airway and this current is divided into nine splits, each split having the same size area as the original current, how much additional air will be obtained? *F.—Pa. (A)*

ANS.—Ignoring shaft resistance and assuming that these nine splits all start from the bottom of the downcast shaft, which, however, is a practical impossibility, the quantity of air circulated by the same power will increase in the same proportion as the number of splits, and the total quantity of air in circulation will then be

$$9 \times 60{,}000 = 540{,}000 \text{ cu. ft. per min.}$$

LIMIT OF SPLITTING

QUES. 957.—What is the effective limit to the method of splitting the air in mine ventilation? *F.—Pa. (B)*

ANS.—The practical limit to splitting exists in the fact that all of the air circulating in the several splits must pass through the same shaft and, generally for a portion of the way, through a single airway before it is divided. This causes a large increase of resistance in the shaft and main airway, which greatly reduces the power or the pressure applied at the mouths of the several splits, and as a consequence the velocity in the several splits is quickly reduced. Were it not for this increase of shaft and main-airway resistance, there would be no limit to splitting.

QUES. 958.—Where air splits are necessary in mines, how would you determine their limit of usefulness? *F.—Pa. (B)*

ANS.—The limit of splitting the air-current is generally determined by the reduction that necessarily takes place in the velocity of the air, considered in connection with the available power of the ventilating machinery. Whenever the velocity of the air-current in any split is too low to produce efficient ventilation at the face, further splitting becomes impracticable except where the power on the air can be increased.

QUES. 959.—What are the advantages of frequent splitting of the air-current, and when is the limit in the number of separate ventilating sections reached? *M.—Ill.*

ANS.—The advantages of splitting the air-current are: (1) A larger quantity of air is circulated by the same power. (2) A large quantity of air is circulated at a low velocity, which is important in the ventilation of gaseous mines. (3) Each district or section of the mine is provided with a separate air-current, and the return of one section of the mine does not pass through another section, but escapes immediately to the main return airway and passes out of the mine. (4) In case of an explosion, the several sections of the mine are more or less isolated and there is less danger of the effect of the explosion extending throughout the mine.

Assuming a constant power on the air and ignoring the resistance of the shafts if the current is split at or near the shaft bottom, the quantity of air produced will be in proportion to the number of the splits. But owing to the shaft resistance and that of the fan, and the added resistance of the main entries to the point where the air is divided, the quantity of air in circulation does not increase in the same ratio as the number of splits, and the velocity of the air in the several splits is, therefore, materially lessened as the number of splits is increased. The reduction of the velocity in splitting, where the power remains constant, determines practically the limit of this means of increasing the circulation without increasing the

power. When the velocity of the current is reduced to the lowest velocity required for the efficient ventilation of the mine, the limit has been reached and no more splits should be made without increasing the power.

QUES. 960.—If you had two air splits in a mine, would it be possible for one of them to work to the disadvantage of the other, and if so, how would you prevent it? *F.—Pa. (B.)*

ANS.—Two air splits may be of such unequal circuit lengths that the shorter one offers less resistance than the longer split, and on this account the quantity circulating in the longer split may be totally insufficient, while that in the short one may be in excess of the ventilation required. To prevent this inequality, a regulator should be fixed in the return airway of the shorter split to equalize the resistances of the two splits. Also, when one split goes to the dip and another to the rise, the dip split will in general take more air, robbing the rise split to do this.

NATURAL SPLITTING OF AIR-CURRENTS

QUES. 961.—If 40,000 cubic feet of air is delivered at the foot of a downcast shaft and there divided into two airways of equal section, but of such unequal length that the resistances are to each other as 4 : 1, what quantity of air will pass in each airway? *I.—Ia.*

ANS.—The question states that the airways are of such length that the resistances are as 4 : 1. The airways being of equal section, and the pressure at the mouth of two splits starting at the same point always being equal, the amount of resistance ($p\,a = k\,s\,v^2$) must also be equal; it would not be possible, therefore, for these amounts to be in the ratio 4 : 1. What the question evidently means is that the airways are of such unequal length that the resistances would be as 4 : 1 for equal velocities; that is, one airway is four times as long as the other; hence, for the same cross-section, the rubbing surface, which offers the resistance to the air-current, is four times as great in one as in the other. The formula for unit pressure in terms of the airway and the quantity of air in circulation is

$$p = \frac{k\,l\,o\,q^2}{a^3};$$

and, since the pressure p is the same in the two airways,

$$\frac{k\,l_1\,o_1\,q_1^2}{a_1^3} = \frac{k\,l_2\,o_2\,q_2^2}{a_2^2};$$

since k, o, and a are the same for the two airways,

$$l_1\,q_1^2 = l_2\,q_2^2 \text{ and } \frac{q_2}{q_1} = \sqrt{\frac{l_1}{l_2}} = \sqrt{\frac{4}{1}} = 2,$$

and

$$q_2 = 2q_1$$

that is, the quantity of air passing in the shorter airway is double the quantity of air passing in the longer airway.

For the longer airway,

$$\frac{1}{3}\times 40{,}000 = 13{,}333+ \text{ cu. ft. per min.}$$

For the shorter airway,

$$\frac{2}{3}\times 40{,}000 = 26{,}667- \text{ cu. ft. per min.}$$

QUES. 962.—100,000 cubic feet of air passes through an airway 6 ft. × 5 ft. in sectional area, and 10,000 feet long, which is divided into three splits as follows: split A is 6 ft. × 6 ft. in section, 2,000 feet long; split B is 6 ft. × 5 ft. in section, 4,000 feet long; and split C is 6 ft. × 4 ft. in section, 6,000 feet long. What quantity of air will pass in each split while the pressure remains the same? *I.—Ia.*

ANS.—The main airway 6 ft. × 5 ft. × 10,000 ft. may be ignored in this calculation, assuming only that the three splits mentioned start from the same point, at the end of this main airway, and that the pressure is the same at the mouth of each of these splits. The quantity passing in each split will then be proportional to the expression $a\sqrt{\frac{a}{s}}$. The area and rubbing surface are first found for each split as follows: split A, $a = 6\times 6 = 36$ sq. ft., $s = 4\times 6\times 2{,}000 = 48{,}000$ sq. ft.; split B, $a = 6\times 5 = 30$ sq. ft., $s = 2(6+5)\times 4{,}000 = 88{,}000$ sq. ft.; and split C, $a = 6\times 4 = 24$ sq. ft., $s = 2(6+4)\times 6{,}000 = 120{,}000$ sq. ft.; and substituting these values,

Split A is $a\sqrt{\frac{a}{s}} = 36\sqrt{\frac{36}{48{,}000}} = .9859$

Split B is $a\sqrt{\frac{a}{s}} = 30\sqrt{\frac{30}{88{,}000}} = .5539$

Split C is $a\sqrt{\frac{a}{s}} = 24\sqrt{\frac{24}{120{,}000}} = .3394$

Total, 1.8792

Then the quantity of air passing in each split is equal to the total quantity multiplied by the ratio of the expression $a\sqrt{\frac{a}{s}}$ for that split to the sum of all these expressions for the several splits.

Split A is $\frac{.9859}{1.8792}\times 100{,}000 =$ 52,464 cu. ft.

Split B is $\frac{.5539}{1.8792}\times 100{,}000 =$ 29,475 cu. ft.

Split C is $\frac{.3394}{1.8792}\times 100{,}000 =$ 18,061 cu. ft.

Total, 100,000 cu. ft.

QUES. 963.—If you have 50,000 cubic feet of air per minute passing into a mine, and the current is divided between two splits whose dimensions are as follows: split A, 5 ft.×8 ft. in section and 3,000 yards long; split B, 6 ft. × 9 ft. in section and 5,000 yards long, what quantity will pass in each airway? *I.—Ia.*

ANS.—In natural splitting the quantity ratio is equal to the potential ratio. The relative pressure potential for any airway is

$$X = a\sqrt{\frac{a}{lo}}$$

Then, substituting values, we have,

Split A, $\begin{cases} a = 5\times 8 & = 40 \text{ sq. ft.} \\ o = 2(5+8) & = 26 \text{ ft.} \\ l = 3{,}000\times 3 & = 9{,}000 \text{ ft.} \end{cases}$

and $$X_a = a\sqrt{\frac{a}{lo}} = 40\sqrt{\frac{40}{9{,}000\times 26}} = .52297$$

Split B, $\begin{cases} a = 6\times 9 & = 54 \text{ sq. ft.} \\ o = 2(6+9) & = 30 \text{ ft.} \\ l = 5{,}000\times 3 & = 15{,}000 \text{ ft.} \end{cases}$

and $$X_b = a\sqrt{\frac{a}{lo}} = 54\sqrt{\frac{54}{15{,}000\times 30}} = .59154$$

then, $$\frac{X_a}{X_b} = \frac{40}{54}\sqrt{\frac{40}{9{,}000\times 26}\times\frac{15{,}000\times 30}{54}} = \frac{.884}{1}$$

or, if $X_b = 1,\ X_a = .884$

Then, calling q_a the quantity of air passing in split A, and q_b the quantity passing in split B per minute, since the total quantity is 50,000 cu. ft.,

$$\frac{q_a}{50{,}000} = \frac{X_a}{X_a+X_b} = \frac{.884}{.884+1} = .469214;$$

and $q_a = 50{,}000\times .469214 = 23{,}461$ cu. ft. per min.

In like manner for split B, we have,

$$\frac{q_b}{50{,}000} = \frac{X_b}{X_a+X_b} = \frac{1}{.884+1} = .53078;$$

and $q_b = 50{,}000\times .53078 = 26{,}539$ cu. ft. per min.

QUES. 964.—In a mine the air splits at the bottom of the downcast. The air-course on one side of the mine is 1,200 feet long and on the other 2,700 feet long; 25,000 cubic feet of air per minute is being sent into the mine. How much of it goes to each side of the mine, all other conditions being the same on both sides? It is desired to have the same amount of air going into each side; how would you arrange to bring this about? After arranging for this, would there be any change in the amount of air entering the mine, the power producing the current remaining the same?

F.—Ind.

ANS.—The quantity varies inversely as the square root of the lengths of the airways, or,

$$q_1 : q_2 = \sqrt{1,200} : \sqrt{2,700};$$

or,

$$\frac{q_1}{q_2} = \sqrt{\frac{1,200}{2,700}} = \sqrt{\frac{4}{9}} = \frac{2}{3};$$

or three-fifths of the air goes into the first airway and two-fifths into the second airway: $\frac{1}{5} \times 25,000 = 5,000$.

$5,000 \times 2 = 10,000$ cu. ft., amount going to the long side.

$5,000 \times 3 = 15,000$ cu. ft., amount going to the short side.

To obtain the same amount of air in each side, split the air again on the long side; or put in a regulator on the short side. By the first plan, there will be more air forced into the mine; by the second, there will be less.

QUES. 965.—Suppose that you have charge of a mine through which large volumes of air are passing in two equal currents of equal resistance, and in which the service of the fan is taxed to its utmost, while the quantity passing is still short of your requirements. The only change you can make in the mine is to make one more split on one side of the shaft. Can you improve the condition of the mine by making this split? Is there any other means of increasing the ventilation of the mine? Answer fully.

M.—Ill.

ANS.—If the only change possible to be made in the ventilation of this mine is the making of one more split on one side of the shaft only, so that the air will then travel in three splits instead of two as before, and the same amount of air is required on the other side of the shaft where no change is made and you cannot increase the power of the fan, under these circumstances it will be of no benefit to make the extra split on one side of the shaft only, for the following reason: The power remaining constant, the quantity of air passing down the shaft cannot be increased without a corresponding loss of pressure, which would result at once in a reduction of quantity on the first side of the shaft, and this would be contrary to the conditions assumed.

QUES. 966.—A drift mine ventilated by a furnace is passing 30,000 cubic feet of air per minute through one split; if another split is added, the area and length of the second airway being the same as the first, how much will the air volume, horsepower, and consumption of coal be increased? Both splits connect with the bottom of the upcast, the temperature of the furnace remains the same, and the shaft resistance is to be disregarded.

I.—Pa. (B)

ANS.—Disregarding the shaft resistance and assuming that the temperature of the furnace shaft remains unchanged, which will result in maintaining the ventilating pressure constant; and assuming that in the addition

of another split starting from the foot of the downcast shaft, the sectional area for the entire circulation and the rubbing surface are both doubled, the volume of air in circulation is doubled and the horsepower required for this circulation will be doubled also, and this will require the consumption of double the quantity of coal, since the consumption of coal is proportional to the horsepower.

REGULATORS

QUES. 967.—What is a regulator? *B.—Ill.*

ANS.—A *regulator* is a partial stopping that closes up a portion of the transverse section of an airway. It may also be described as a stopping with a small opening through it that can be enlarged or diminished according to the quantity of air required.

QUES. 968.—How can air-currents be regulated so as to furnish the different proportions of air needed in the several districts or workings? *I.—Ia.*

FIG. 1. BOX REGULATOR

ANS.—The air-current of a mine will always divide into two or more currents when there are two or more separate ways by which the air can travel through the mine to reach the upcast. The air will divide itself naturally between these several routes, or passages, according to the resistance offered by each; and this division is called the natural division of the air. The proportionate division of an air-current, or any division other than the natural division is accomplished by means of regulators. The regulators in use are of two forms, known as the box regulator and the regulator door. The former is shown in Fig. 1, and consists of a door or brattice

built usually in the return airway, because this position will generally interfere less with the mine haulage. This form of regulator is provided with a movable slide or shutter by which the opening may be increased or diminished at will, thus regulating the supply of air in the split that it controls. The other form of regulator, shown in Fig. 2, consists of a door *a b* at the mouth of two splits, so arranged that its cutting edge *a* is presented to the intake current. This door is provided with a set lock, so that it may be fixed in such a position as to divide the air-current into any desired proportions, between the two airways. This latter form of regulator consumes somewhat less power than the former, since each split is then ventilated under its own natural pressure; but the use of one or the other of these regulators will depend wholly on the arrangement of the haulage roads with respect to the ventilation of the mine.

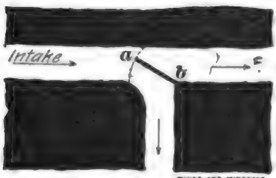


FIG. 2. DOOR REGULATOR

QUES. 969.—For what purposes are regulators used? *F.—Pa. (A)*

ANS.—Regulators are used to make any proportionate division of the air-current required. Without the regulator, the natural division of the air often proves insufficient for the proper ventilation of the longer entries and supplies too much air to the shorter splits. The use of a regulator in one or more splits in a mine increases the quantity of air circulating in all the other splits. A regulator introduces a resistance in the path of the air-current of a district that would otherwise receive too much air at the expense of other districts that require more air.

QUES. 970.—When is a regulator required in a mine? *M.—Ill.*

ANS.—When it is desired to make a proportional division of the air-current, or any division of the air-current other than the natural division.

EFFECT OF USING A REGULATOR

QUES. 971.—How is the ventilation of a mine affected by the placing of a regulator in the air-current? *F.—Pa. (B)*

ANS.—By placing a regulator in the path of a ventilating current a resistance is introduced that reduces the quantity of air passing in that airway or split and forces it into another split, which, from having a less sectional area or being longer, may offer a greater resistance than the first airway. The resistance due to the regulator added to the natural resistance of the first split is equal to the natural resistance of the second split, or the free split. Regulator resistances are necessary whenever the air-current must be divided differently from the natural division.

QUES. 972.—Does a regulator increase the friction of the air circulating through the mine, and in what manner? *F.—Pa. (B)*

ANS.—Any change made in a circulation, to produce a proportionate division of the air, or to produce any division other than the natural division, will result at once in an increase of the unit of ventilating pressure for that split in which it is desired to circulate a larger quantity of air than it receives by the natural division of the current. Since an increase of the pressure and quantity of air circulating in one of the airways is accomplished by means of one or more regulators placed in the other airways, it is true that the regulator causes an increase of ventilating pressure in one airway or split. In the other airways, however, if the regulator is placed at the mouth of the split, there will be a reduction both of the unit of ventilating pressure and of the quantity of air passing in each. The question of the increase of friction for the entire mine is one dependent wholly on the rubbing surfaces in the several splits and the division of air accomplished by the regulator, and may prove to be an increase or a decrease of friction.

QUES. 973.—A mine is ventilated through two airways of equal length; in one of these airways *A*, the intake and return are each 6 ft. × 9 ft. in section, and in the other airway *B*, 6 ft. × 12 ft. The total quantity of air in circulation is 60,000 cubic feet per minute. A regulator placed in *B* is so adjusted as to make the circulation in that airway 30,000 cubic feet per minute. What effect has this regulator on the ventilation of airway *A*, and on the fan and the fan engine? *I.—Ill.*

ANS.—The total quantity of air in circulation before the regulator is placed, being 60,000 cu. ft. per min., its natural division between the two airways will be about as follows: split *A*, 25,000 cu. ft., split *B*, 35,000 cu. ft. The effect of placing the regulator in *B* and so adjusting it as to reduce the quantity of air passing in that split to 30,000 cu. ft. per min. will be to increase the total mine resistance, and as a result the total quantity of air in circulation will be reduced. There will be an increase in the volume of air passing in split *A*, however, but this increase will not equal the decrease in *B*. With the same steam supplied to the engine running the fan, the speed of the fan will be increased. The reason for this is that owing to the increased mine resistance, a less quantity of air is passing through the fan, which therefore handles a less weight of air per minute. This decrease in the weight of air handled is offset by an increase in the speed of the fan and of the engine, resulting also in a slight increase of the power applied.

QUES. 974.—A current of 9,000 cubic feet of air per minute is passing through a regulator, the difference of pressure on the two sides of the regulator is equal to .7 inch of water gauge. How far is the regulator shutter open, if it is 1 foot in depth? *I.—Ia.*

Ans.—The usual method of estimating the size of opening in a box regulator, when the difference of pressure between the two sides of the regulator is given in inches of water gauge, is by using the formula,

$$a = .00038 \frac{Q}{\sqrt{i}}$$

in which a = area of the opening, in square feet;
Q = quantity of air passing, in cubic feet per minute;
i = water gauge, in inches.

Substituting the given values in this formula, the area of the opening is

$$a = .00038 \frac{9{,}000}{\sqrt{.7}} = 4.088 \text{ sq. ft.}$$

If the height of the opening is 1 ft., the width of the opening will be $4.088 \div 1 = 4.088$ ft.

Ques. 975.—A pressure of 1.5 inches of water gauge gives in an open airway 24,000 cubic feet of air per minute. It is desired to reduce the quantity of air in that passage to 6,000 cubic feet per minute by the introduction of a regulator, what will be the required pressure? If the velocity in the open airway is 600 feet per minute, what is the velocity after the regulator is introduced?
I.—Ia.

Ans.—Though the question does not so state, it is assumed that the effective power on the air remains unchanged, and, therefore, $u = q\,p$ is constant. Hence, the quantity varies in this case inversely as the pressure,

$$\frac{p_2}{p_1} = \frac{q_1}{q_2}$$

Then, substituting values

$$\frac{p_2}{1.5 \times 5.2} = \frac{24{,}000}{6{,}000} = 4,$$

and $$p_2 = 4 \times 1.5 \times 5.2 = 31.2 \text{ lb. per sq. ft.}$$

For the same sectional area, or area of passage, since $q = a\,v$, the quantities vary as the velocities, and

$$\frac{v_2}{v_1} = \frac{q_2}{q_1};$$

or, substituting values,

$$\frac{v_2}{600} = \frac{6{,}000}{24{,}000} = \frac{1}{4},$$

and $$v_2 = \frac{600}{4} = 150 \text{ ft. per min.}$$

Ques. 976.—In a certain mine, there are two sections ventilated by separate air-currents. The combined length of the intake and return in one of these sections is 6,000 feet; the number of men employed is 100; and the number of mules, 10. In the other

division, the length of the airway is 3,000 feet; the number of men, 110; and the number of mules, 7. What will be a proper distribution of the air sent into the mine, and what steps must be taken to secure such a distribution? *M.—Ill.*

Ans.—The number of men and mules employed in these sections will require practically an equal distribution of air to each section of the mine. The airways having the same sectional area, the natural division of the air will be inversely proportional to the square root of the length of the airways, or the quantity ratio for the two airways is equal to the square root of the inverse length ratio, that is,

$$\frac{q_1}{q_2} = \frac{\sqrt{l_2}}{\sqrt{l_1}} = \sqrt{\frac{3,000}{6,000}} = \sqrt{.5} = .707$$

That is, for every 1,000 cu. ft. of air passing in the shorter airway there is 707 cu. ft. passing in the longer one. To make an equal division of the air, a regulator must be placed in the shorter split and so adjusted as to give the required result.

CHAPTER X

CONDUCTING AIR-CURRENTS

MEANS USED

QUES. 1000.—What means are necessary in order to properly conduct an air-current to the working face? Mention, also, the essential points necessary to be observed with respect to each of these means. *B.—B. C., Canada*

ANS.—The principal means are as follows: doors, stoppings, air bridges (overcasts or undercasts), brattices, canvas doors, or curtains. The essential points in regard to each of these are as follows:

Doors.—These should be as air-tight as possible. The door frame should be well set, in a part of the entry where the condition of the roof and floor is good, if there is freedom of choice in location. It usually happens, however, that there is no choice in regard to the location of the door. It is all the more important, therefore, that the door frame should be heavy and well set in the roof and floor. It should be well calked between the frame and the ribs. The door should be hung on the side toward the air, and with sufficient fall, so that it will always close itself.

Stoppings.—A good mine stopping can always be built from the refuse of the seam, or from the slate taken from the roof or bottom. Double walls are usually laid with this slate, 1 ft. or 18 in. apart, or more, according to the amount of waste material at hand. The space between these two walls of slate is filled with the fine dirt taken from the roadway, and packed tight to the roof of the seam. A wall of slate, no matter how thick, is not sufficient. It will deflect the air-current only so long as the pressure is low; but as the mine advances and the ventilating pressure is increased, this class of stoppings will be very inefficient. It often becomes necessary to plaster the outside of stoppings with the clay taken from the floor of the seam, a little salt often being added to the water. This form of stopping is very useful to seal off old rooms and abandoned workings, to prevent the gases from escaping into the airway. Stoppings are also built of timber, brick, and even of concrete.

Air Bridges.—The essential points of an air bridge or air crossing are that it shall be strongly made and air-tight. Overcasts, where possible, are to be preferred to undercasts, for several reasons: (1) An undercast

is liable to be flooded easily by mine drainage. (2) An undercast renders the air-current passing through it dusty, as the dust from the roadway is continually sifting through the floor. This would be objectionable if the current were an intake current. (3) It is a difficult matter to maintain an air-tight undercast on account of the constant travel over the bridge. Air bridges are subject to the destructive effects of an explosion perhaps more than any other partition built in a mine. It has been suggested to build the bridge with a trap door, which would act as a relief valve to the pressure caused by the explosion, and thus prevent its destruction by the force of the blast. This plan, however, has not met with much favor, as the door, in all probability, would be blown from its hinges by the force of the blast, and would not fall shut as expected.

Brattices.—The essential points of brattices are that they shall be air-tight, that there shall be sufficient sectional area behind the brattice for the passage of the current, and that the brattice be carried sufficiently near the face to be of real benefit to the men working there.

Canvas Doors.—These should be hung so that the canvas laps well, except when they are intended to act as a regulator by allowing some of the air-current to pass through them. The canvas should be heavy duck canvas.

MINE DOORS

QUES. 1001.—How should all doors affecting ventilation be adjusted in a mine? *F.—Pa. (A)*

ANS.—By the Anthracite Mine Law of Pennsylvania all doors used in assisting or in any way affecting the ventilation shall be so hung and adjusted that they will close automatically.

QUES. 1002.—What are the provisions of the Anthracite Mine Law regarding doors in mines? What are their purposes? How should they be erected? *F.—Pa. (A)*

ANS.—The Anthracite Mine Law of Pennsylvania requires that all doors assisting or in any way affecting the ventilation, be so hung and adjusted that they will close automatically. That all doors, except such self-acting doors as are approved by the inspector of the district, shall have an attendant whose constant duty shall be to open and close the door for persons and cars passing through them. That all main doors be so placed that when one door is open another door having the same effect on the current shall be closed; this means that double doors shall be used at all main points in the airway, and only one of them shall be open at any one time.

The law also requires that an extra main door shall be provided and kept standing open in such position as to be out of reach of accident, and so fixed that it may be closed immediately in the event of an accident to the doors in use.

The main doors shall be substantially secured in stone or brick laid in mortar or cement, unless otherwise permitted in writing by the mine inspector.

QUES. 1003.—What are the requirements of the Illinois Mine Law in reference to trap doors and the mine examiners' report? *E.—Ill.*

ANS.—Section 19 of the Revised Mining Law of Illinois reads as follows:

(*e*) All permanent doors in mines used in guiding and directing the ventilating currents, shall be so hung and adjusted as to close automatically. (*f*) At all principal doorways through which cars are hauled, an attendant shall be employed for the purpose of opening and closing said doors when trips of cars are passing to and from the workings. Places for shelter shall be provided at such doorways to protect the attendants from being injured by the cars while attending to their duties.

Section 12 reads as follows:

(*i*) Each State Inspector of Mines shall at the close of the official year, to wit: After June 30, of every year, prepare and forward to the Secretary of the Bureau of Labor Statistics, a formal report of his acts during the year, in the discharge of his duties, with any recommendations as to legislation he may deem necessary on the subject of mining, and shall collect and tabulate upon blanks furnished by said Secretary, all desired statistics of mines and miners within his district, to accompany said annual report.

QUES. 1004.—What advantages are to be derived from ventilating a mine without the use of doors? *F.—Pa.* (*B*)

ANS.—The haulage roads are left unobstructed; both the expense of repairing the doors and the expense of trappers are avoided, as also the dangers of drivers running into a closed door. When doors are used, there is always the liability of these being left open, resulting in a derangement of the ventilation of the entire mine, which in gaseous mines may result in a serious explosion. In case of an explosion in the mine, a door will often be destroyed where an overcast may resist the force of the explosion. In such a case, the circulation in a portion of the mine is destroyed until the door is repaired.

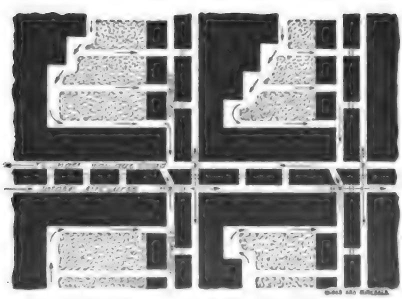


FIG. 1

QUES. 1005.—Draw a plan of a mine in which no ventilating doors are used; show the direction of the air-currents by arrows. *F.—Pa.* (*B*)

ANS.—The plan shown in Fig. 1 requires no doors; but necessitates working the coal on one side only of each pair of cross-entries; and is therefore particularly applicable to seams of considerable pitch. The system cannot be economically applied to flat seams where coal is worked upon both sides of the cross-entries, necessitating haulage upon both the intake and the return air.

QUES. 1006.—What pull is required to open a trap door 6 ft. × 6 ft. in size, the handle being 6 inches from the side, the pressure on the door showing a water gauge of $1\frac{1}{4}$ inches, and friction being neglected? *M.—Ill.*

ANS.—The total pressure on the door is

$$6 \times 6 \times 1.25 \times 5.2 = 234 \text{ lb.}$$

This pressure is exerted at the center of the door, and acts with a lever arm of 3 ft. The lever arm of the pull is $6 - .5 = 5.5$ ft. In order to open the door, the moment of the pull on the handle at the start must be equal to the moment of the pressure exerted at the center of the door, and hence, denoting the pull by P,

$$P = \frac{234 \times 3}{5.5} = 127.6 \text{ lb.}$$

STOPPINGS

QUES. 1007.—What is a stopping and for what purpose is it made? *E.—Ill.*

ANS.—An air stopping is a brattice, wall, or partition fixed in a cross-cut between rooms or airways for the purpose of preventing the passage of the air-current through such opening. There are two classes of stoppings, permanent and temporary stoppings. The permanent ones are built with brick or stone and pointed with mortar to make them air-tight, or of slate filled in with dirt. The temporary stoppings are either made with planks or canvas sheets. All stoppings are made to completely close the cross-cut or opening. The use of stoppings is to confine the ventilating currents of a mine within the paths in which they are intended to move.

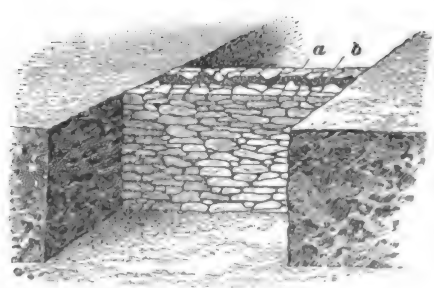


FIG. 2. STOPPING

QUES. 1008.—Of what materials would you construct permanent stoppings to secure duration and economy? Give reasons. *F.—Ia.*

ANS.—Permanent air stoppings are often constructed by building a double wall of slate or rock taken from the waste of the mine, Fig. 2, and filling the space between them, which is from 6 to 8 in. wide, or even more, with sand or more commonly fine dust taken from the roadways, as shown in the illustration. In sealing off abandoned workings, stoppings are often made of brick laid in cement, an 8-, 13-, or even a 17-in. wall being used for this purpose. The stopping should be built of good, solid material to prevent the leakage of air or gas, which is the purpose of the stopping.

QUES. 1009.—How should air stoppings be built in mines to conduct and maintain the air-currents at the face of the workings? Explain how you would have the work done. *F.—Pa.* (*B*)

ANS.—Air stoppings should be substantially built with double walls of brick or slate, the space between being filled with dirt taken from the roads, or other fine material; the outside of the stopping may also be plastered over with mortar or clay to render the stopping air-tight.

QUES. 1010.—Describe how you would construct a good, cheap, durable brattice in break-throughs on entries and in rooms.
F.—Ind.

ANS.—A simple and efficient stopping or brattice for break-throughs between entries is readily made by building a double wall of roof slate across the opening or break-through; these walls should be, say, 18 in. thick, and a space from 8 in. to 12 in. wide should be left between them. The space between the walls is filled with fine dust taken from the roadways, or with sand packed tightly to the roof. This form of stopping is very efficient and prevents any serious leakage of the air-current. It is usually sufficient to stop all break-throughs in rooms by a simple walling of the refuse of the seam, except in special cases where they are required to deflect the air to the face of the rooms for a considerable distance, and the face is difficult to ventilate, as in the case of rooms running to the rise. In this case, it may be necessary to use slack or fine dirt in building the walls for stoppings.

QUES. 1011.—What provision should be made in a mine generating firedamp to control the currents of air between the intake and return airways? What method of construction would you suggest, and what is the character of the material that should be used? *I.—Pa.* (*A*)

ANS.—The Anthracite Mine Law of Pennsylvania provides that the intake and return air passages for any particular district of a mine must be separated by a pillar of coal or stone, except where cross-cuts are necessary in such dividing pillar for the purpose of ventilation, traffic, or drainage. All cross-cuts between the intake and return air passages of a mine shall be closed when necessary, by substantial stoppings made of brick or other suitable building material, laid in mortar or cement, whenever practicable. In no case shall said stopping be constructed of plank except for temporary purposes. Where doors are necessary between the intake and return entries, double doors shall be employed. The framework of all main doors shall be substantially secured in stone or brick laid in mortar or cement, except as otherwise permitted in writing by the inspector.

QUES. 1012.—In a pitching seam, where it is necessary to build stoppings in the old stalls to conduct the air along the level, state

where you would consider the proper place to build the stoppings. Give reasons. *B.—B. C., Canada*

Ans.—The stoppings should be built in the mouth of the stalls so as to interfere with the main air-current as little as possible. Assuming a gaseous seam, and assuming also that it is desired to close entirely the old stalls, the building of the stoppings should commence at the return end, each stall being sealed off in regular order until the intake end is reached, the stopping in the mouth of this stall being sealed last. The reason for this is to avoid the possible accumulation of an explosive body of gas in any of the stalls, which would occur if the intake stoppings were sealed first.

AIR CROSSINGS

Ques. 1013.—What is an air crossing or air bridge? *F.—Pa. (A)*

Ans.—An air crossing or air bridge is an arrangement of air passages in a mine by which one current of air is made to pass under or over another current. This may be accomplished by cutting a separate air passage in the roof strata overlying the seam, or in the underlying strata forming the floor. In the former case, the crossing is called an overcast, and in the latter an undercast. Sometimes the air passage forming the crossing is

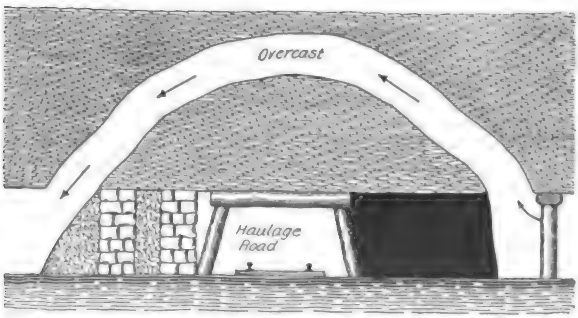


Fig. 3. Overcast Separated From Main Road by Rock

separated from the main passage by a good thickness of natural strata, as shown in Fig. 3, at other times the crossing is constructed in the roof strata or in the floor of the seam, and is separated from the main passage by a bridge built of timber, heavily planked and sealed to prevent the leakage of air from the air crossing into the main passageway, as shown in Fig. 4.

Ques. 1014.—Make a sketch showing how you would construct an overcast. *M.—Ill.*

Ans.—See preceding question.

QUES. 1015.—What useful purpose do overcasts and undercasts serve in mine ventilation, and which kind would you approve and why? *F.—Pa. (B)*

ANS.—The purpose of overcasts and undercasts is to enable the main ventilating currents of fresh air to be split and to be conducted across one another for the separate ventilation of the panels or districts into which the mine is divided. By this means, it is possible to conduct the return air from a certain panel or district, over or under the main intake airway, and pass it into a cross-cut leading to the main return airway. The overcast air bridges are, for general use, better than the undercast, as they cannot be flooded and closed like the undercasts; they are more easily maintained air-tight, and the dust of the road does not sift into the airway.

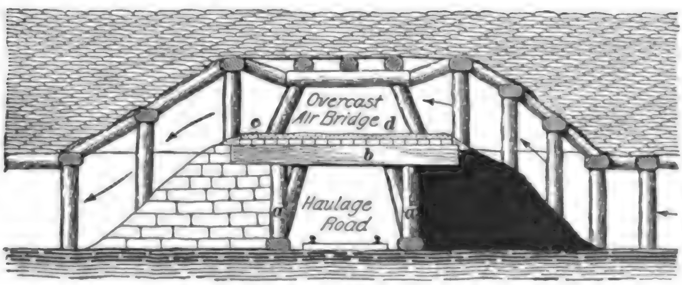


FIG. 4. OVERCAST DIRECTLY ABOVE ROAD

QUES. 1016.—What do you consider the best to use for an overcast in a mine that is producing CH_4, or firedamp: stone, brick, iron, or wood? Give your reasons. *E.—Ill.*

ANS.—There will always be some difference of opinion in regard to the best material to be used in constructing an air bridge. Fireproof material, as stone, brick, and iron is good, but wood has the advantage of being tough and yielding, which is important in case of an explosion occurring in the mine. Where a stone, brick, or iron bridge would be destroyed by the force of an explosion, a wooden bridge supplied with proper doors is often uninjured. Wood is also more easily handled and fitted in place than iron, and by yielding shows the pressure to which it is subjected. Many prefer an overcast driven in the solid strata.

QUES. 1017.—What are the legal requirements relating to the construction of air stoppings and overcasts in bituminous mines? *F.—Pa. (B)*

ANS.—The Bituminous Mine Law of Pennsylvania requires the construction of an overcast not less than 4 ft. wide and 5 ft. high, for the use of persons in the mine, and to provide egress from the workings on each side of the main slope and airway; such overcast to be driven in the solid

strata or built of substantial masonry; also, all overcasts or air bridges in mines generating firedamp in sufficient quantities to be detected by ordinary safety lamps must be built of masonry or other incombustible material of ample strength, or driven through solid strata; all stoppings between the main intake and return airways must be substantially constructed of suitable material approved by the mine inspector of the district; all stoppings along airways shall be properly built.

CHAPTER XI

MEASURING AND TESTING AIR-CURRENTS

INSTRUMENTS USED FOR TESTING AIR-CURRENTS

QUES. 1050.—Name and describe the different instruments used to examine the condition of the atmosphere of a mine, showing the principle and application of each. *B.—Pa.* (*B*)

ANS.—The gaseous condition of the mine atmosphere is determined by means of the safety lamp. For this purpose, a common Davy lamp is generally preferred. The Davy lamp is fully described in Chapter IV, also its application describing the amount of gas present in the mine air.

Atmospheric conditions are determined by the thermometer and the barometer. The *thermometer* is the ordinary house thermometer, and is employed to ascertain the temperature of the air at the point where the velocity of the current is measured, since any change in the temperature of the air affects at once the volume or quantity of air in circulation. For this reason, it is always important to note the temperature of the air in connection with the anemometer readings in careful investigations. There are two important thermometer scales, the Fahrenheit, mostly used in the United States and England, and the centigrade scale, used largely on the Continent. The corresponding points in these scales are the freezing point of water, 32° F., and 0° C.; and the boiling point of water 212° F., and 100° C. In the Fahrenheit scale 212° − 32° = 180°, corresponding to 100° of the centigrade scale, the ratio being $\frac{180}{100} = \frac{9}{5}$. The following formulas are useful in changing any Fahrenheit reading to the corresponding centigrade reading or vice versa:

$$C = \frac{5}{9}(F-32);$$

$$F = \frac{9}{5}C+32$$

The *mercurial barometer*, shown in Fig. 1, is the form of barometer usually employed in mining; it is placed at the surface, near the mouth of the mine. Some barometers are made to be self-registering. The instrument consists of a glass tube about 3 ft. in length closed at one end. The

tube is filled with mercury from which the air has been expelled by boiling. When the tube is inverted and the open end submerged in a vessel containing mercury, the column of mercury in the tube sinks to such a level or height as will be supported by the atmospheric pressure. At sea level, the height of the mercury column is 30 in., under normal atmospheric conditions. At elevations above the sea level, the reading of the barometer is less; and at elevations below the sea level, the reading is greater, the difference in barometric height being about 1 in. for every 90 ft. rise or fall from sea level. The principle of the barometer is as follows: The weight of the atmosphere pressing upon the surface of the mercury in the vessel balances the weight of the mercury column in the tube; there being a vacuum (no pressure) above the mercury column, the calculated weight of this column for any given area of cross-section shows exactly the atmospheric pressure upon the same area.

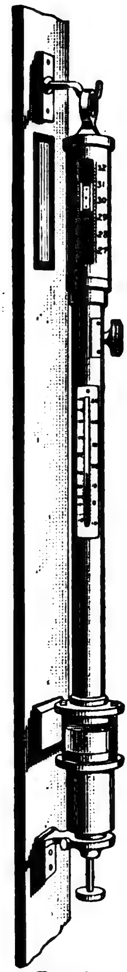


Fig. 1
Barometer

The *aneroid barometer* is sometimes used instead of the mercurial barometer, since it is more easily portable; this form of barometer consists of a brass box from which the air has been exhausted. One side of the box is corrugated and is sensitive to the least variation in the pressure of the atmosphere upon it. The movement of the side of the box caused by the variation of the atmospheric pressure, is communicated by a set of levers and gearing to a pointer on the dial or face of the instrument. The readings of the aneroid barometer are made to correspond to those of the mercurial barometer. The application of the barometer to mining is found in the fact that any change in the atmospheric pressure affects sooner or later the volume of the gases contained in the abandoned workings of the mine. A fall of the barometer shows a decrease of atmospheric pressure, which results in an expansion of the volume of gases in the mine workings. A large amount of gas is thus thrown out on the airways, which often results in causing a dangerous condition of the air-current.

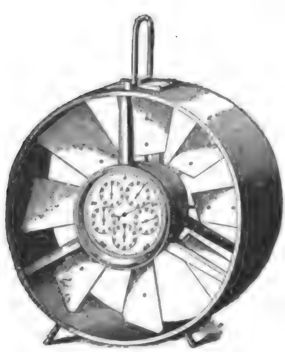


Fig. 2. Anemometer

The conditions relative to the circulation of the air-current in the mine are determined by the use of the anemometer and water gauge. The *anemometer*, Fig. 2, is an instrument consisting of a small vane revolving in a circular frame. The revolutions of the vane are recorded by means of several pointers on the face of the instrument. There is usually one large pointer that makes one revolution for each hundred

revolutions of the vane. The dial for this pointer has one hundred divisions, each division indicating one revolution of the vane, or 1 ft. of velocity in the air-current. The smaller dials are arranged decimally by a system of gear-wheels to register 1,000, 10,000, etc. feet, for each revolution of their respective pointers. The anemometer is used to determine the velocity of the air passing in the airway; the inclination of the blades being such that 1 ft. of lineal velocity in the passing air-current produces one revolution of the vane.

The *water gauge*, Fig. 3, consists of a glass tube about ½ in. in diameter bent in the form of a letter **U**, and having its two ends open. One of these open ends is bent at a right angle and is fitted with a brass extension or tube, which is inserted in a small hole bored in a door or brattice to which the instrument is attached in the mine. The purpose of the instrument is to measure the difference of pressure between two airways. Having placed some water in the bend of the tube, one end of the water gauge is inserted in the hole in the brattice, using a cork, if necessary, to make a tight joint. The two ends of the gauge are thus subjected to different pressures, the pressure upon the intake airway always being greater than that upon the return. This causes the water to sink in the arm of the water gauge open to the intake, and to rise a corresponding amount in the other arm. The difference of the level of the water in the two arms of the gauge is read from an adjustable scale, as shown in the figure. One end of the glass tube is drawn to a narrow opening to exclude dust, while the other end is bent to a right angle, and passing back through the standard to which the tube is attached, is cemented into the brass tube that passes through a hole in the partition or brattice, when the water gauge is in use. The bend of the tube is contracted to reduce the tendency to oscillation in the height of water column. Each inch of water-gauge reading corresponds to a ventilating pressure of 5.2 lb. per sq. ft., and the ventilating pressure p is calculated from the water-gauge reading i by the formula

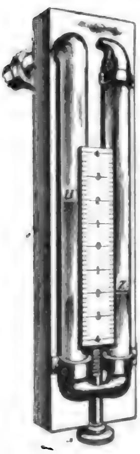


Fig. 3
Water Gauge

$$p = 5.2 \times i$$

Ques. 1051.—What instruments would you employ as an inspector to determine the character of atmosphere of coal mines?
I.—Pa. (A)

Ans.—The Anthracite Mine Law of Pennsylvania requires that the mine inspector shall provide himself with the most modern instruments and appliances. He will therefore need a watch, anemometer, water gauge, safety lamp, barometer, and thermometer. Of these, the first three are important in determining the quantity of air in circulation in the mine, and the ventilating pressure. The last three are used in determining the character and condition of the mine air in circulation and its pressure and temperature. Another machine, known as the Shaw gas tester, has been introduced at some of the larger mines and is used by some mine inspectors

for determining the percentage of gas in the air-current, samples of the mine air being brought from the mine to the office in rubber bags and then analyzed.

PRINCIPLE OF BAROMETER

QUES. 1052.—How can you ascertain, by the barometer, the pressure of the atmosphere on the earth's surface, per square inch and per square foot? Will it indicate the friction of air in mines, and why? *F.—Pa. (B)*

ANS.—Since the atmospheric pressure balances the mercury column of the barometer, the weight of the mercury column indicates the exact pressure of the atmosphere upon an area equal to the sectional area of the mercury column. Hence, to obtain the pressure of the atmosphere per square inch, calculate the weight of a mercury column whose height is equal to the height of the barometer and whose sectional area is 1 sq. in. One cubic inch of mercury weighs .49 lb.; hence, by multiplying .49 by the height of the barometer, in inches, the pressure of the atmosphere per square inch will be obtained. Thus, if the barometer stands at 30 in. the atmospheric pressure per square inch is $.49 \times 30 = 14.7$ lb. per sq. in. The pressure per square foot is found by multiplying the pressure per square inch by 144, since there are 144 sq. in. in 1 sq. ft. When the barometer stands at 30 in., the atmospheric pressure per square foot is $14.7 \times 144 = 2,116.8$ lb.

This question probably intends to ask whether the barometer can be used for measuring the ventilating pressure in a mine. The barometer measures the total pressure, or the pressure above a vacuum, and cannot be used to ascertain the ventilating pressure, which means the pressure producing ventilation in the mine, or the amount the pressure in the intake airway exceeds that in the return. The ventilating pressure is always the difference between two pressures, while the barometric pressure is the total pressure due to the weight of the atmosphere.

USE OF ANEMOMETER

QUES. 1053.—Describe the anemometer and state its use in connection with mine ventilation. *M.—Ill.*

ANS.—The anemometer, shown in Fig. 2, consists of a small vane having its blades inclined to the plane of revolution. The inclination of the blades is such that one revolution of the vane corresponds to a lineal movement of the air of 1 ft., so that when the vane makes sixty revolutions in 1 min. the air is traveling at a velocity of 60 ft. per min. The revolutions of the vane are communicated to a recording dial on the face of the instrument by means of a series of gears. There is at the top of the instrument a small catch by which the hands of the dial may be thrown into or out of gear,

thus enabling the instrument to record the movement of air for an exact period of time as noted by the watch. The anemometer is used to ascertain the velocity of an air-current in an airway.

USE OF WATER GAUGE

QUES. 1054.—Describe the water gauge and state its use in mines. *F.—Pa. (A)*

ANS.—The water gauge is described fully in reply to Ques. 1050. The instrument is attached to a door or brattice in the mine. A small hole is bored in the door or brattice located between the main intake *C*, Fig. 4, and the main return airway *D*. By this arrangement, one end of the gauge is open to the intake airway while the other end is open to the return airway. These two ends are thus subject to different pressures, the pressure on the intake always being greater than that on the return airway. This causes the water to sink in the arm of the water gauge open to the intake, and to rise a corresponding amount in the other arm.

The water gauge shown in Fig. 3 has a reading of 2 in., one column being depressed to *Z*, while the other column has risen to *H*. The scale

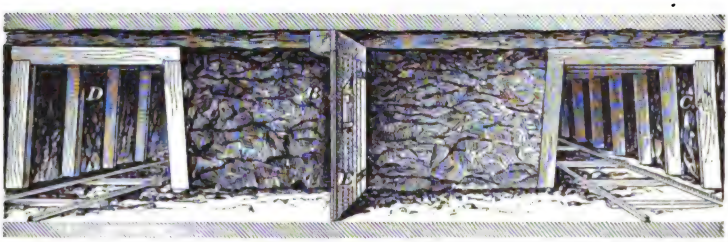


FIG. 4

here shown is graduated in ½ in. and reads from zero both up and down, so that the reading of either arm gives the correct reading for the entire gauge. The scale is often made adjustable, so that its zero can always be brought to the exact level of the water in each arm before placing the gauge in position. It is evident that the mine pressure registered by this water gauge is equivalent to a water column of 2 in., or will support a column of water 2 in. high. This causes a pressure upon each square foot equal to the weight of 2 in. of water in a cubical box 1 ft. square on the bottom. Since 1 cu. ft. of water weighs 62.5 lb., 1 in. of water covering a base 1 ft. square will weigh $62.5 \div 12 = 5.2$ lb. Each inch of water gauge is thus equivalent to a pressure of 5.2 lb. per sq. ft.

In using the water gauge, it is necessary to be sure that it is not too far removed from the air-current on either side of the brattice; also, that its openings are not subjected to the velocity of the intake or return currents. That is to say, the open end should not point into a current, but should be protected from the velocity of the current. Another essential point

in the use of the water gauge is that it should be used in a vertical position. There is upon most gauges a level tube for leveling the instrument. This level tube is upon the top of the instrument, and shows when the gauge is in a vertical position. It is essential that the stopping should not leak; it must be perfectly air-tight, especially about the instrument. Any leakage of the air through the brattice decreases the pressure; and if this takes place too close to the instrument, there will be a local decrease of pressure recorded in the reading of the gauge.

QUES. 1055.—What is a water gauge? Where and why is it applied? If the pressure producing ventilation is 10.4 pounds per square foot, what is the water gauge? *I.—Ia.*

ANS.—A water gauge is a **U**-shaped glass tube in which water is placed. Both ends of the tube are open, respectively, to the intake and return pressures; the difference between these pressures is measured on a scale, in inches. The reading of the water gauge, in inches, multiplied by 5.2 gives the unit of ventilating pressure or the pressure per square foot producing ventilation.

The water gauge is used in connection with the anemometer to ascertain the horsepower of the air-current. When the pressure producing ventilation is 10.4 lb. per sq. ft., the water-gauge reading is $10.4 \div 5.2 = 2$ in.

QUES. 1056.—Where would you apply the water gauge? Does it increase or decrease as the workings extend, all other conditions remaining the same, and why? *B.—Pa. (B)*

ANS.—A water-gauge reading should be taken as near to the foot of the downcast or the mouth of a split as possible. The instrument is attached to a brattice or door dividing the main intake and return airways.

The water gauge increases with the extent of the workings, other conditions remaining the same, because the extended workings represent an increased rubbing surface, consequently, an increased mine resistance and pressure.

QUES. 1057.—What are the uses of the following instruments in connection with coal mines: anemometer, thermometer, barometer, and water gauge? *I.—Ia.*

ANS.—The anemometer is used to determine the velocity of an air-current for the purpose of calculating the quantity of air in circulation in an airway.

The thermometer is employed to ascertain the temperature of the air current, since any change in the temperature of a current will affect at once the volume or quantity of air in circulation.

The barometer is used to indicate the atmospheric pressure, since any change in atmospheric pressure affects the volume of the gases in the abandoned workings of the mine.

The water gauge is used to measure the ventilating pressure, or the pressure producing circulation in any airway, this being the difference between the intake and return pressures.

DETERMINING QUANTITY OF AIR

QUES. 1058.—How would you determine the amount of air circulating through a mine? *F.—Pa. (A)*

ANS.—The amount of air circulating through a mine is found by multiplying the velocity of the air-current by the sectional area of the airway. The velocity is measured by an instrument called the anemometer; the sectional area of the airway is calculated from the measured dimensions of the cross-section of the airway.

QUES. 1059.—How would you ascertain the quantity of air circulating through a mine? *F.—Pa. (B)*

ANS.—The quantity of air in circulation is obtained by taking careful measurements of the velocity of the air-current by means of the anemometer at a point selected in the airway where the sectional area is uniform and the airway is straight. The size of the airway is carefully measured at this point to obtain its average sectional area in square feet. To obtain a fair average reading, the anemometer is held in a position at right angles to the direction of the current, and somewhat inby and to one side of the observer's body; the instrument is moved slowly and carefully to different positions in the cross-section of the airway so as to obtain an average reading; this may require 2 or 3 min. The total reading of the anemometer is then divided by the time in minutes required for taking the observation, to obtain the velocity of the current in feet per minute; the quantity of air in circulation, in cubic feet per minute, is then found by multiplying the sectional area of the airway, in square feet, by this velocity. In practice, when reading the anemometer, it is not customary to add a constant making allowance for the inertia of the instrument, since there are other more important conditions that offset this effect, such as the diminution of the sectional area of the airway by the body of the observer, whereby the observed velocity is somewhat increased.

QUES. 1060.—How do you measure air in mines? What instruments are necessary? Assuming the dimensions of the air-course to be 4 ft. 6 in. × 7 ft., what is the velocity of the current when 10,000 cubic feet of air is passing? *F.—Ind.*

ANS.—First, measure the velocity of the current by holding the anemometer for, say 1 minute in different parts of the section of the airway; then measure the height and the width of the airway at this point, and calculate the sectional area of the airway, in square feet; then multiply the area by the velocity of air passing.

The instruments required are, anemometer, tape line, and timepiece.

$$\frac{10{,}000}{4.5 \times 7} = 317+ \text{ ft. per min.}$$

QUES. 1061.—An anemometer registers 30,000 feet velocity per hour in an airway 8 ft. × 5 ft.; what is the volume of air passing per minute, and how will you ascertain whether the anemometer is in good working order? *F.—Pa. (B)*

ANS.—The quantity of air passing per minute in this airway, assuming that the anemometer has registered an average velocity for the airway, will be

$$\frac{30{,}000}{60} \times 8 \times 5 = 20{,}000 \text{ cu. ft. per min.}$$

The anemometer should be examined to see that none of the blades are bent, and when the stop is loosened the vane should start to revolve at once if the instrument is in good order. The complete testing of the anemometer is always done by the instrument maker, but an approximate test may be made by what is known as the flash test. Some powder is exploded at a given point and the time is noted for the smoke to travel from this point to another point on the air-current at which the anemometer is held. In this experiment the smoke of the flash is borne upon the swiftest portion of the air-current flowing in the center of the airway, and this central velocity of the air-current is considerably above the average velocity. In applying such a test for the purpose of checking the accuracy of the anemometer, the instrument should be held in the center of the airway during the entire time. Care must be taken not to obstruct the area of the airway with the body of the observer. The stop that throws the registering apparatus into gear must be operated at the moment that the flash is observed, and again, at the first smell of the powder in the air-current, or at its first appearance at the anemometer, the registering apparatus must be promptly thrown out of gear. The difference of readings in the anemometer or the amount the anemometer registers should correspond to the distance from the flash to the instrument. The small interval of time lost on account of the personal equation of the observer will perhaps be offset by the disturbance of the current at the point where the flash is fired. The sectional area of the airway should be uniform throughout the entire distance.

REGULATIONS OF LAW AS TO MEASURING AIR-CURRENT

QUES. 1062.—How often does the Anthracite Mine Law of Pennsylvania require the air-currents to be measured? By whom measured? When must the air reports be sent to the office of the mine inspector? *F.—Pa. (A)*

ANS.—The Anthracite Mine Law requires the air-currents to be measured once a week.

These air measurements must be made by the inside foreman or his assistant.

The report must be sent to the mine inspector before the twelfth day of each month, for the previous month.

QUES. 1063.—What are the provisions of the Bituminous Mine Law of Pennsylvania regarding air measurements? *F.—Pa.* (*B*)

ANS.—The Bituminous Mine Law of Pennsylvania requires the mine foreman to measure the air at least once a week at the inlet and outlet of the mine and at or near the faces of the entries, and to keep a record of such measurements.

QUES. 1064.—Describe any apparatus with which you are familiar, used for determining the percentages of gases found in the atmosphere of mines. *I.—Pa.* (*A*)

ANS.—The Shaw gas tester is used for this purpose, the mine air to be tested being brought to the surface in bags, as the instrument cannot be taken into the mine. Its construction and mode of action are as follows: The pistons of two pump cylinders, respectively called the air and gas cylinders, are attached to a graduated beam or lever. The air cylinder is stationary while the gas cylinder and the head of its connecting-rod are movable, to enable them to be set by adjusting screws to any required distance from the fulcrum. By altering this distance of the gas cylinder from the fulcrum of the beam, any proportion of air and gas may be pumped from the sample bags attached to suction pipes into the ignition chamber (a strong brass chamber with a loose piston).

Before the mine air can be tested to ascertain the percentage of gas required to bring it to the explosive point, the explosive point of some gas, such as illuminating gas, must be determined. To do this, pure air is used in the air cylinder, while the gas to be tested is pumped into the gas cylinder. At first, only a small percentage of this gas is pumped into the ignition chamber with the pure air from the air cylinder, and no explosion takes place. The percentage of gas is increased slightly by setting the gas cylinder farther from the fulcrum of the beam; and another mixture of gas and pure air is pumped into the ignition chamber. This is continued until the mixture becomes slightly explosive, which is indicated by the loose piston in the ignition chamber being driven lightly against the gong, thus sounding the alarm. The explosive point of the gas used being determined, the air cylinder is connected to the bag containing the mine air to be tested. If the mine air contains much gas, a violent explosion would be obtained in the ignition chamber. To avoid this, however, the gas cylinder is set back somewhat, toward the fulcrum, to allow for the gas that is thought to be in the mine air, and in this manner, it is soon determined how many parts of gas are contained in the mine air used. Thus, suppose that 96 parts of pure air and 4 parts of illuminating gas are feebly explosive, and when using mine air in place of pure air, only 1.5 parts of the illuminating gas are required to produce an explosion; then,

$$\frac{4-1.5}{100-1.5} = \frac{2.5}{98.5} = 2.53 \text{ per cent.}$$

determines the percentage of gas in the mine air, basing the calculation upon 100 parts of the mixture in each case.

The approximate percentage of marsh gas in mine air may also be indicated by special forms of safety lamps, such as the Ashworth alcohol lamp, the Clowes hydrogen lamp, or the Pieler testing lamp, fitted with a scale by which the height of the flame is indicated. There are also various forms of sight indicators, such as the Beard-Mackie, that can be attached to any safety lamp. These consist of a number of platinum wires that brighten when heated and thus serve as a scale for determining, approximately, the percentage of gas present in a mixture.

CHAPTER XII

ESTABLISHING A CIRCULATION OF AIR IN MINE VENTILATION

GENERAL PRINCIPLES GOVERNING THE FLOW OF AIR

QUES. 1100.—Explain the principles governing the flow of air in mines. *I.—Pa.* (*A*)

ANS.—Air always flows from a point of higher pressure toward a point of lower pressure. The difference between these two pressures is called the ***unit*** of ventilating pressure. This unit pressure p is the pressure per square foot of sectional area. It is the total pressure $p\,a$ that moves the air-current against the mine resistance. The mine resistance is due to the friction of the air rubbing on the sides, top, and bottom of the airways. The *total* or ventilating pressure $p\,a$ is always equal to the mine resistance, or the resistance offered by the airways to the passage of the air-current. If there were no resistance there would be no pressure. The total pressure $p\,a$ multiplied by the velocity of the air-current, in feet per minute, gives the work $p\,a\,v$ in foot-pounds per minute, or the power on the air, which is the effective power of the ventilating motor.

QUES. 1101.—State by what two methods air is set in motion so as to produce a current. *F.—Pa.* (*A*)

ANS.—Air is set in motion as follows: (1) By decreasing the pressure at the outlet of a mine. For example, in the use of a furnace, the air in the upcast or furnace shaft is rarefied and made lighter by the heat of the furnace, thus reducing the pressure at the foot of the shaft, due to the weight of the air in the shaft. Likewise, in the use of the exhaust fan at the mouth of the upcast shaft, the atmospheric pressure is reduced at the top of the shaft; or, in the use of the steam blast, the air in the upcast is heated to a higher temperature by the steam and made lighter. In all these cases, the pressure at the foot of the upcast shaft is decreased. This causes a movement of the air through the airways from the downcast or intake of the mine toward the upcast or outlet. (2) Another method for producing an air-current in the airways of a mine is to increase the pressure on the air at the intake of the mine. This is done by means of the blowing fan, which by its action establishes a pressure greater than that of the atmosphere. Another example is found in the use of the waterfall or trompe, by which the pressure of the

air at the intake is increased mechanically. In both of these cases, the air, as before, moves from a point of higher pressure toward a point of lower pressure, thus providing a current through the airways of the mine. In the first of these two methods, the mine is ventilated under a pressure below that of the atmosphere; in the second method, the mine pressure is above that of the atmosphere.

QUES. 1102.—How and why does a fan or furnace cause a current of air to flow through the workings of a mine? *F.—Ala.*

ANS.—An air-current will always be produced in an airway when there is a difference of pressure between the intake and return openings of the airway, because air flows from a point of higher pressure toward a point of lower pressure. This difference of pressure is called the unit of ventilating pressure and is caused, in the case of the furnace, by raising the temperature of the upcast column above that of the downcast column. In the case of the fan, the difference of pressure is caused by the centrifugal action of the fan.

MOTIVE COLUMN

QUES. 1103.—Explain what is meant by the term motive column, as applied to ventilation. *F.—Pa. (B)*

ANS.—The term ***motive column*** is often used to express the unit of ventilating pressure in mine ventilation. It is an imaginary column of air having a base of 1 sq. ft. and a height such that the weight of the air column will be equal to the unit of ventilating pressure, or the pressure per square foot in the airway. The motive column may be assumed to consist of either upcast or downcast air; but for the same pressure, the motive column of upcast air will have a greater height than that of downcast air. The latter is more commonly used since it is the excess of weight of the downcast column over that of the upcast column that forms the motive column. This is illustrated in Fig. 1 where the portion *b c* of the downcast column balances the weight of the entire upcast column *d e*, and the remaining portion of the downcast column *a b* acts as the motive column to force the air through the mine. The weight per square foot of this column equals the ventilating pressure.

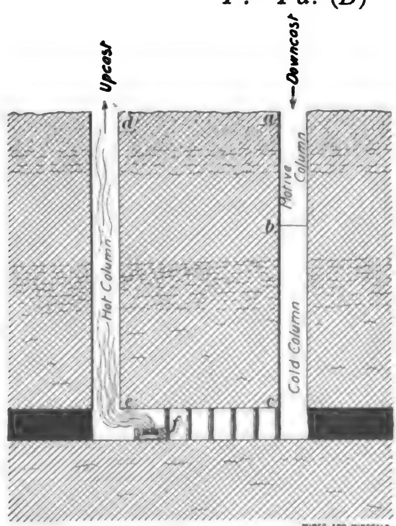


FIG. 1

QUES. 1104.—If the quantity of air in the downcast weighs 1,800 pounds, the depth of the shaft being 300 feet, and the difference of the weight of air in the two shafts is 250 pounds, what will be the length of the motive column, assuming that the shafts are of the same size and depth? *F.—Pa. (B)*

ANS.—If the weight of the entire air in the downcast shaft is 1,800 lb., as the question states, the depth of the shaft being 300 ft., the weight of a layer of air in this shaft, 1 ft. in thickness, will be $1{,}800 \div 300 = 6$ lb. The difference of the weight of the air in the two shafts being 250 lb., the length of the motive column that will produce the same pressure is

$$250 \div 6 = 41\tfrac{2}{3} \text{ ft.}$$

QUES. 1105.—The weight of air in a downcast shaft 325 feet deep is 1,950 pounds, at a temperature of 60° F., and a barometer of 30 inches; and the difference of the weight of air in the two shafts is 294 pounds. What is the length of the motive column? What is the area of the downcast shaft, in square feet? *I.—Ia.*

ANS.—The weight of 1 cu. ft. of the downcast air in this case is

$$w = \frac{1.327 \times B}{460 + t} = \frac{1.327 \times 30}{460 + 60} = .0766 \text{ lb., nearly}$$

The depth of the shaft being 325 ft., and the total weight of air in the shaft 1,950 lb., the area of the shaft is

$$a = \frac{1{,}950}{.0766 \times 325} = 78.3 \text{ sq. ft.}$$

The difference of the weight of air in the two shafts being 294 lb., the unit of ventilating pressure is

$$294 \div 78.3 = 3.75 + \text{lb. per sq. ft.}$$

The motive column of downcast air corresponding to this pressure is, then,

$$M = \frac{p}{w} = \frac{3.75}{.0766} = 48.95, \text{ say } 49 \text{ ft.}$$

QUES. 1106.—If the weight of a cubic foot of air is .0766 pound and the water gauge is 1.5 inches, what is the height of the motive column? *F.—Pa. (B)*

ANS.—Since 1 in. of water gauge corresponds to a pressure of 5.2 lb. per sq. ft. the height of the motive column, in the case given, is calculated by dividing the pressure per square foot, corresponding to 1.5 in. of water gauge, by the weight of 1 cu. ft. of air. Thus,

$$M = \frac{p}{w} = \frac{1.5 \times 5.2}{.0766} = 101.8 + \text{ ft.}$$

QUES. 1107.—What will be the height of the motive column in a case where the depth of the downcast is 300 feet, and the

temperature of the downcast 32° F., and temperature of the upcast 48° F.? *I.—Ia.*

Ans.—There are two formulas for motive column, the one giving its value in terms of the downcast air, and the other in terms of the upcast air. The height of these motive columns will be different since they are composed of air of different densities, the former being the shorter of the two columns since it is composed of the heavier air. These two formulas are as follows:

Downcast air, $$M = D\frac{T_2 - t_1}{460 + t_2}$$

Upcast air, $$M = D\frac{T_2 - t_1}{460 + t_1}$$

Applying these formulas to this example, we have, for the motive column in terms of the downcast air at a temperature of 32° F.,

$$M = 300 \times \frac{48-32}{460+48} = 300 \times \frac{16}{508} = 9.4 \text{ ft.}$$

For the motive column in terms of the upcast air, we have

$$M = 300 \times \frac{48-32}{460+32} = 300 \times \frac{16}{492} = 9.7 \text{ ft.}$$

MEANS AND SYSTEMS FOR ESTABLISHING AN AIR-CURRENT

Ques. 1108.—Name the different means for producing ventilation in mines. *F.—Pa. (A)*

Ans.—The different means for producing an air-current in a mine may be classified as follows: *Natural means*, wind pressure, waterfall (trompe), air column produced by the difference between the temperature of the mine air and that of the outside atmosphere; *use of steam*, steam jet; *furnace ventilation*, artificial heat produced by a furnace built at the bottom of the upcast shaft; *mechanical ventilation*, volumetric machines (obsolete), disk fans (propeller type), centrifugal fans, exhaust fans, and blow-down fans. Besides these means of producing a current of air in a mine, the several means and appliances for conducting the air through the airways so as to secure the efficient ventilation of the mine are as follows: doors, curtains or canvas doors, stoppings, brattices, air bridges (overcasts and undercasts).

Ques. 1109.—What methods do you think the best and safest for producing a current of air in a mine? *M.—Ill.*

Ans.—Furnaces and fans are most widely used; the former are very efficient in deep shafts where no gas is present. Centrifugal fans are the most reliable means of ventilation, and the safest where gas is given off in the mine and a large volume of air is required.

QUES. 1110.—Describe the different systems of ventilation in use. F_1.—*Ala.*

ANS.—The systems of ventilation may be classified under two general heads, as natural ventilation and artificial ventilation. Natural ventilation is any circulation of air in rooms or passageways, produced by natural existing agencies, such as surface wind, falling water, the natural heat of the rock surfaces of mines in winter, and their cooling effects in summer. Artificial ventilation is any circulation of air in rooms or passageways produced by artificial means, as the application of artificial heat to produce an air column, in furnace ventilation, or the use of exhaust steam from the pumps discharged into the upcast shaft, or by the use of some mechanical means to produce a ventilating pressure in the airway, as by steam jet or fan.

Ventilation may also be classed under two general systems, according as it is produced by a pressure less or greater than that of the atmosphere. In the former case, the system of ventilation is known as the *vacuum*, or *exhaust*, system; while in the latter case, it is called the *plenum*, or *blowing*, system. All forms of ascensional ventilation, as natural ventilation or furnace ventilation, as well as that accomplished by the steam jet or the exhaust fan, belong to the former; while the trompe, wind cowl, and blow-down fan are each types of the latter.

QUES. 1111.—What is the best mode of ventilation? F_1.—*Ala.*

ANS.—Of the several modes of ventilation, that produced by the fan is generally considered the best and most reliable; exhaust steam, furnace, and natural ventilation are all more or less affected by weather conditions; there are many cases, however, where fan ventilation is not justified and resort is had to some of the other plans. The weather conditions as to temperature and wind may be such as to change the direction of the air-current in natural ventilation and the ventilation at such times may become practically nothing, which would not be true of a fan, and only partially true of a furnace. In furnace ventilation, however, when the natural air column formed in the shaft or in the slope or dip workings opposes the furnace column, the effect is to diminish the volume; the same is also true in all ventilation produced by exhaust or live steam or where the ventilation is produced by differences in temperature between the downcast and upcast.

QUES. 1112.—Describe the cheapest and best system of ventilating mines. F_2.—*Ala.*

ANS.—The most economical and practical system of ventilation will depend in any case on the conditions, the quantity of air required, depth of shaft, length of airways, etc. In small mines or in the earlier development of larger mines, a furnace is often used in the absence of gas. A fan, however, will prove the most economical as the development increases. The general plan of ventilation of mines should be such as to provide a separate current or split of air for each district of the mine to enable the return air of each district to be carried directly into the main return airway.

QUES. 1113.—What are the systems of ventilations in use in this country, and cite the conditions that would make each system more available than others, taking safety and economy into consideration? *F_1.—Ala.*

ANS.—The systems of ventilation may be classed under two general heads, as natural ventilation and artificial ventilation (Ques. 1110.) Natural ventilation is unreliable and can only be applied to the ventilation of small workings at certain seasons of the year. The method of producing an air current by a wind cowl is adapted chiefly to shaft sinking; it is likewise unreliable. The method of ventilating by means of a steam jet is more reliable, but can only be applied to shafts while sinking, or to small workings. The trompe can only be used as a means of ventilating mines in localities where there is an abundant supply of water that can be relied on at all seasons of the year. It is also necessary that natural drainage be provided for the discharge of the water after it has fallen through the trompe in the shaft; this is usually accomplished by means of a drainage tunnel driven from the surface to the foot of the shaft. The system finds its greatest application in mountainous districts. The furnace at the foot of an upcast shaft is an efficient means of establishing a ventilating current, especially in deep mines. In the ventilation of gaseous seams, the furnace cannot be used, however, with any degree of safety, although frequently the gaseous current is conducted into the upcast shaft, above the furnace, by means of a dumb drift; the furnace being fed by a small current of fresh air direct from the downcast. The furnace furnishes a very convenient means of ventilating small mines, and is often preferred to the more expensive mechanical motors or fans.

The various forms of centrifugal ventilators or fans are now used at almost all the larger mines and many of the smaller ones, as this class of ventilator is coming rapidly into favor, and is considered the most reliable, safe, and economical, under all conditions.

QUES. 1114.—There are three modes of ventilation now in use in Indiana, the blowing and exhaust fans and the furnace. Name some conditions under which each of these three modes will have an advantage over the others; also the disadvantages of each. State which would be your preference under ordinary circumstances. *F.—Ind.*

ANS.—Furnace ventilation is an effective and cheap method of ventilation for deep seams and when no gas is present. A furnace is easily constructed and maintained, and its cost of operation is usually considered a small factor on account of the abundance of fuel at hand. Comparative tests, however, show that fan ventilation is more economical. One disadvantage in the use of a furnace under ordinary conditions consists mainly in the difficulty of starting the furnace fire after a short period of idleness. This difficulty is greater in some mines than in others owing to the large quantities of blackdamp generated. In gaseous mines, the furnace is a

dangerous means of ventilation; it must be supplied with a dumb drift to carry the gaseous current into the shaft at a point considerably above the furnace, to prevent ignition of the gas, and explosion. Its use under such conditions, however, is always a menace to the safety of the mine.

In the use of any form of fan, the ventilation of a mine is more completely under control. One advantage of this form of ventilation consists in the fact that the ventilating apparatus is at the surface, where it can be readily reached in case of accident. Another advantage is in the ability to increase the amount of circulation quickly when desired. Fan ventilation is practically independent of the depth of the shaft as far as power is concerned, and is more efficient in shallow shafts than in deep ones, on account of the decreased resistance of a shallow shaft. A third advantage consists in the ability to change the direction of the air-current passing in the mine by reversing the action of the ventilator. The difference between an exhaust fan and a blow-down fan is practically very small, each being adapted to different conditions in the mine.

The exhaust fan is adapted to the ventilation of gaseous mines where the intake airway is made the main haulage road, the fan being then located over the upcast, and the hoisting shaft being made the downcast. The blow-down fan cannot be used under these conditions, unless it is located at or near the hoisting shaft and doors placed at the shaft bottom, which is generally impracticable. The exhaust fan is to a certain extent less efficient than a blow-down fan especially in mines yielding a large quantity of firedamp, on account of working on air of decreased density. This effect, however, is small in comparison with the practical conditions previously mentioned and which alone should determine the use of the exhaust fan.

The blow-down fan is adapted to the ventilation of mines where the haulage is performed on the return airway, which is usually the case in non-gaseous mines, as well as in many gaseous mines where it is possible to render the return airways safe for haulage. There are numerous reasons why haulage may be better performed on the return where this can be rendered safe, than on the intake of a mine. The blow-down fan is working on pure outside air which is under the increased mine pressure, and is to an extent more efficient than an exhaust fan. Under ordinary circumstances, the blow-down fan is preferable in case the condition of the mine can be rendered safe to allow of haulage upon the return air-current.

NATURAL VENTILATION

QUES. 1115.—Explain briefly the difference between natural and artificial ventilation. *I.—Pa. (A)*

ANS.—Natural ventilation is any circulation of air in a mine or airway produced by natural existing agencies, as wind, falling water, the natural heat of the strata in winter, and their cooling effect in summer. Artificial ventilation is the circulation of air produced by artificial means, whether by artificial heat, as in furnace ventilation, or the use of steam, or by some mechanical means.

QUES. 1116.—Which is the more reliable, mechanical or natural ventilation, and why? *F_1.—Ala.*

ANS.—Mechanical ventilation is the more reliable because it does not depend to the same extent on atmospheric conditions, which are very changeable.

QUES. 1117.—Describe the principles of natural ventilation. *F.—Pa. (A)*

ANS.—Briefly stated, the principle on which natural ventilation depends is the lack of the equilibrium or difference in weight between two connecting air columns, which causes a movement of the air in the direction of the lower pressure or the lighter air column.

QUES. 1118.—What conditions are necessary to produce natural ventilation? Explain by diagram the course of the current in summer and winter. *F.—Pa. (A)*

ANS.—The conditions producing natural ventilation must be such as to produce a difference of pressure between the intake and the outlet of the airways of a mine; and this difference of pressure must be caused by natural means; as, for example, the natural heat of the mine or wind pressure at the mouth of the intake.

Fig. 2 represents the natural ventilation of a drift *m* connecting with an air-shaft *a b*. At the left (*a*) is shown the direction of the current

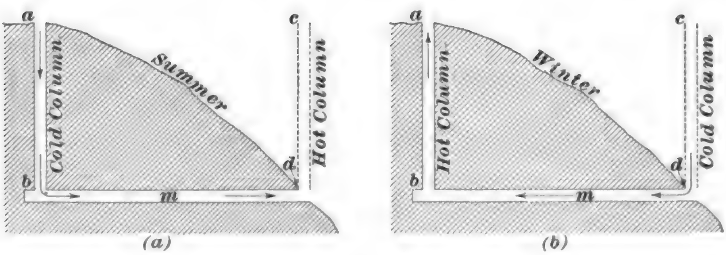


FIG. 2

in summer; at the right (*b*) is shown the direction of the current in winter. In summer, the outside air being warmer than the air in the mine, the air column in the shaft *a b* is heavier than the outside air column *c d*. In winter, these conditions are reversed; the outside air being cooler, the outside column *c d* is heavier than the shaft column *a b*. The air in the airways always moves from the point of higher pressure toward the point of lower pressure, thus causing a reversal of the current as the season changes.

QUES. 1119.—Under what conditions does natural ventilation work best in a mine? *F.—Pa. (A)*

ANS.—Natural ventilation is always most effective when the difference between the temperatures of the outside and inside air is greatest; it also

increases with the depth of the mine below the surface. Natural ventilation is therefore stronger in winter and summer than in spring or autumn, since there is then a greater difference in the temperatures of the outside and inside air.

QUES. 1120.—Why is the ventilation in a mine better on a clear, frosty, winter day than on a day in midsummer? *E.—Ill.*

ANS.—When the system of ventilation employed in the mine is ascensional, on a winter day the mine air being warmer than the outside air, there will be formed in the mine, or in the shaft, a natural air column that will assist the ventilation of the mine. On the other hand, in summer, the mine air being cooler than the outside air, a natural air column will be formed in the mine that will retard the general circulation. These conditions are reversed, however, in all cases where the ventilation in the mine is not ascensional.

QUES. 1121.—State what you know of the conditions by which the natural flow of air through a mine is governed. *F.—Pa. (A)*

ANS.—The ventilating pressure is caused by the natural motive column formed in the shaft or slope opening, or in the dip or rise workings of the mine, or both. Such motive column is produced by the rarefaction of the mine air due to its increased temperature, the warmer and lighter air of the mine being forced upwards and out of the shaft by the cooler and heavier outside air that falls to take its place. The quantity of air circulated by the motive column will depend again on the resistance of the mine. The quantity of air in circulation is decreased as the mine resistance is increased, but not necessarily in the same proportion.

QUES. 1122.—If a mine has two openings, one 200 feet higher on the surface than the other, and the temperature of the air is the same in and out of the mine, what will be the nature of the ventilation? *F.—Pa. (A)*

ANS.—Since there is no difference of temperature, there will be no natural ventilation in this case, except such as may arise from wind pressure.

QUES. 1123.—If a tunnel 1 mile long is driven through a mountain from east to west, in which direction will the air flow morning and evening, and why? F_1.—*Ala.*

ANS.—Assuming that the mountain through which the tunnel is driven is high enough to cause different conditions of temperature upon its eastern and western slopes, and disregarding the effect of prevailing winds at the openings of the tunnel, the air-current through the tunnel in the morning will be from west to east, and in the evening from east to west. The reason for this is the difference in the density of the air due to the difference in the temperature upon the two sides of the mountain. The difference in temperature is caused by the heat of the sun, the temperature being higher and the air lighter upon the eastern side in the morning, and upon the western side in the evening.

QUES. 1124.—A mine has two openings, one 200 feet higher than the other, at the surface; the outside temperature being 80° F. and the inside temperature 45° F., in what direction will the air-current pass? What is the ventilating pressure, in pounds per square foot, the barometer being 30 inches? *F.—Pa. (A)*

ANS.—Air will flow into the mine through the higher opening and discharge from the lower opening, whatever the kind of opening.

The pressure producing ventilation may be found as follows:

$$p = \left(\frac{1.324 \times B}{460+t} - \frac{1.324 \times B}{460+T}\right) \times D = 1.324\ B\ D \frac{T-t}{(460+t)(460+T)};$$

substituting the given values,

$$p = 1.324 \times 30 \times 200 \times \frac{80-45}{(460+45)(460+80)}$$

$$= 7{,}944 \times \frac{35}{505 \times 540} = 1.02 \text{ lb., nearly}$$

QUES. 1125.—If, with an upcast temperature of 180° and a downcast temperature of 48°, the pressure is 5.75 pounds per square foot, what will the pressure be if the upcast temperature is raised to 200°? *M.—B. C., Canada*

ANS.—Assuming the depth of the upcast equal to that of the downcast, the motive column, downcast air, is given by the formula

$$M = D\left(\frac{T-t}{460+T}\right)$$

Then, the motive column or the pressure, for the same depth of shaft, is proportional to the expression, $\frac{T-t}{460+T}$, and

$$\frac{180-48}{460+180} : \frac{200-48}{460+200} = 5.75 : x,$$

and

$$x = 5.75 \times \frac{152}{132} \times \frac{640}{660} = 6.42+ \text{ lb. per sq. ft.}$$

FURNACE VENTILATION

QUES. 1126.—What is the difference between natural ventilation and ventilation produced by a furnace? *M.—Ill.*

ANS.—In natural ventilation, the air column producing the circulation is caused by the natural heat of the mine. In furnace ventilation, the air column is produced by the artificial heat of the furnace. In other respects, these two systems of ventilation are identical.

QUES. 1127.—State fully the chief points to be considered in the construction of a ventilating furnace. *F.—Pa. (B)*

Ans.—The chief points to be considered in the construction of a mine furnace are: (*a*) The location of the furnace near the foot of the upcast shaft. (*b*) Size of grate required. (*c*) Area of air passages through and around the furnace. A mine furnace should be located a sufficient distance back from the foot of the upcast or furnace shaft, say 10 or 15 yd., depending on the depth of the shaft, for the purpose of giving a better draft and avoiding the danger of the ignition of the shaft timbers by the sparks and flame of the furnace. The size of a furnace grate is an important factor in the construction of a mine furnace. The factors determining the size of grate are as follows: Depth of furnace shaft and horsepower of the air-current, as determined by the quantity of air in circulation and the water gauge or unit pressure producing such circulation. These factors are shown from the formula giving the area of grate for a mine furnace,

$$A = H\frac{34}{\sqrt{D}},$$

in which A = area of furnace grate, in square feet; D = depth of furnace shaft, in feet; H = horsepower of air-current.

The length of the furnace bars is determined by the distance in which good firing can be accomplished, and should not exceed 5 ft. The width of the furnace is then determined by dividing the area as obtained by the use of the formula, by the length of the bars.

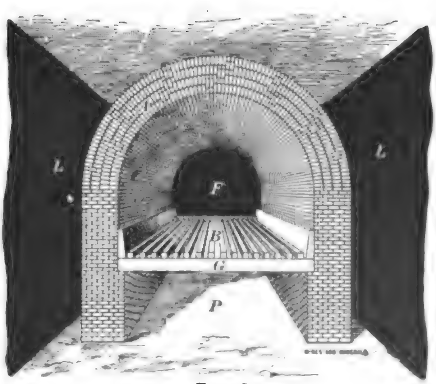


Fig. 3

A good mine furnace is shown in Fig. 3. The roof above the furnace should be well secured by crossbars of railroad iron. Preferably, a brick arch A is thrown over the furnace grate B and carried back to the foot of the shaft at F, to prevent the ignition of the coal L L on each side of the furnace. Surrounding this arch, above and on each side, is an air space, as shown in the figure, protecting the coal and the roof, and absorbing and carrying into the shaft almost the entire heat of the furnace. The sectional area of this air space and that under the arch A should be such as to accommodate the quantity of air in circulation at a velocity of, say not to exceed 20 or 25 ft. per second. The grate bars B rest in notches of the cross-bearing bars G. The ash-pit P and the fire-arch A are lined with firebrick. It is important to shut off the back of the ash-pit by a brick wall to increase the draft of the furnace.

Ques. 1128.—What requisites, other than a full supply of coal, will be necessary to develop the greatest amount of heat and work out of your ventilating furnace? *F.—Pa.* (*B*)

Ans.—A correct area of fire-grate surface to secure the perfect combustion of the coal; a sufficient sectional area of the air passages through and around the furnace to allow the required quantity of air, expanded by the heat of the furnace, to pass without unnecessary resistance; intelligent firing.

Ques. 1129.—The depth of a shaft is 400 feet and the power required in the ventilation of the mine is 37.8 horsepower, find the required area of the furnace grate necessary to produce this power.

Ans.—The area of grate surface is found as follows:

$$A = H\frac{34}{\sqrt{D}} = 37.8\left(\frac{34}{\sqrt{400}}\right) = 64.26 \text{ sq. ft.}$$

Ques. 1130.—Is furnace ventilation better in winter than in summer, and if so, why? *F_2.—Ala.*

Ans.—Yes; in winter there is generally a greater difference between the temperature of the outside air and the average temperature of the furnace shaft, than in summer, and on this account furnace ventilation is more effective in the winter season.

Ques. 1131.—At what season of the year and under what conditions will a furnace give the best results? *I.—Pa. (B)*

Ans.—The furnace always gives the best results in the winter season, when the outer air is colder than the mine air and the upcast column thereby rendered more effective.

Ques. 1132.—In the use of furnaces, which will give the greater ventilating pressure, deep or shallow shafts? *F_2.—Ala.*

Ans.—In furnace ventilation, the unit of ventilating pressure, in pounds per square foot, is directly proportional to the depth of the furnace shaft, other conditions being the same. For this reason, under like conditions, deep shafts will give a greater ventilating pressure than shallow shafts.

Ques. 1133.—Why does an air stack, the top of which is higher than the mouth of the mine, or exhaust steam, cause a current of air to travel in the mine? *F_1.—Ala.*

Ans.—It is the difference between temperatures of the upcast and downcast columns of air that creates a ventilating pressure or air column, which causes the air to travel through the mine passages and workings. A stack is usually placed above a furnace shaft and its effect is to lengthen the upcast column, and thus increase the ventilating pressure. Exhaust steam discharged at the bottom of the upcast shaft rises in the shaft owing to its density being less than that of air, the specific gravity of steam being .6235. This steam is often made to issue from a jet, and the force of its discharge adds somewhat to its efficiency in producing an upward current in the shaft. The steam may also heat the air in the upcast.

QUES. 1134.—What dangers to life and property are to be guarded against where ventilation is produced by a furnace?
M.—B. C., Canada

ANS.—In furnace ventilation, there is always present the danger of the ignition of the coal or the timbers of the shaft by sparks or the heat of the furnace, and in gaseous mines there is danger of ignition of the gas which would cause a disastrous explosion.

QUES. 1135.—Under what conditions may the air-current reverse in a mine ventilated by a furnace or fan? *F.—Pa. (A)*

ANS.—Assuming that the furnace or the fan is working normally, the only conditions that can give rise to a reversal of the current are conditions that will arise from some such an occurrence as a mine explosion or mine fire, which will derange the ventilation and cause the formation of at least a temporary motive column counteracting the motive column produced by the ventilator, whether fan or furnace.

EFFECT OF ATMOSPHERIC CHANGES ON THE VENTILATION OF A MINE

QUES. 1136.—How is the ventilation of a mine affected by a rise or fall of the atmospheric pressure? Answer fully. *M.—Ill.*

ANS.—The principal effect of any change in barometric pressure on the ventilation of the mine is manifested by the action of the air and gases contained in the old workings of the mine, and which are often highly explosive. They occupy and completely fill a space in the old workings under the existing barometric pressure. Any fall of the barometer will result in the expansion of the gases in the old workings, and a large amount of explosive gas is thus forced out from the old workings on to the airways of the mine, rendering the air-current explosive. In order to prevent such an occurrence, the ventilating current should be increased immediately upon the slightest indication of a fall of the barometer. A fall of the barometer always takes place from 3 to 6 hours in advance of its effect in the mine, which gives ample time to provide against the danger resulting therefrom, if the mine officials are watchful. At some mines, the barometers are supplied with an alarm indicator, which makes known any fall of the barometer. If the ventilation of the mine is effected by means of a fan, any fall of the barometer will decrease the density of the air, and thus make the fan less efficient than before. In like manner, any rise of the barometer will increase the density of the air, and increase the efficiency of the fan.

QUES. 1137.—What will be the effect on the ventilation of an old mine with numerous unventilated old rooms and entries in it, by a fall of the barometer? Where will this effect be most noticeable? *M.—Ill.*

ANS.—The first part of this question has been fully answered in reply to the preceding question.

The effect will be most noticeable in the immediate vicinity of the abandoned rooms or workings from which the gas issues and in the return air-current from this district.

QUES. 1138.—Does an increase or decrease of the pressure of the atmosphere affect the volume of air passing through a mine? Explain. *F.—Pa. (B)*

ANS.—In furnace ventilation, an increase or decrease of atmospheric pressure does not affect perceptibly the volume of air passing through a mine. Any increase or decrease of atmospheric pressure will cause a corresponding decrease or increase of the volume of air in circulation, caused by the expansion or contraction of the air. The density of the air will also change with the pressure, but this does not appreciably affect the frictional resistance incident to the passage of the air-current through the mine. In fan ventilation, however, the increase or decrease of the density of the air caused by a change of atmospheric pressure increases or decreases the efficiency of the fan quite appreciably. If the power applied to the fan shaft remains the same, any atmospheric change that increases the density of the air causes a decrease in the number of revolutions made by the fan per minute, or a decrease of the speed of the fan; but any atmospheric change that decreases the density of the air will produce an increase in the speed of the fan. Thus, a fan making 100 rev. per min. in dry air, temperature 60° F., the barometer being 30 in., will probably make only about 93 rev. per min. when the temperature falls to 30° F. below zero; while at a temperature of 100° F. the same power applied to the fan will probably produce a speed of about 103 rev. per min. If, however, the power applied to the fan is altered so as to maintain the speed of the fan constant, any atmospheric change that increases the density of the air will likewise increase the quantity of air delivered, and any atmospheric change that decreases the density of the air will likewise decrease the quantity of air delivered. Thus, a fan delivering 80,000 cu. ft. of dry air per min. at a temperature of 0° F. will deliver 81,822 cu. ft. when the temperature falls to 30° F. below zero, at the same speed; or 75,365 cu. ft. when the temperature rises to 90° F., at the same speed, the barometer being 30 in. Or again, a fan delivering 76,000 cu. ft. of air per min. at a temperature of 60° F., the barometer being 29 in., will deliver 77,700 cu. ft. of air at the same speed of the fan and temperature of the air, when the barometer stands at 31 in. These figures show the effect of atmospheric change to be considerable in fan ventilation.

QUES. 1139.—Do changes of temperature affect the ventilation of the mine, and if so, how? *F_2.—Ala.*

ANS.—In mine ventilation, a change of temperature is important wherever there are air columns to be affected by such change. The effect is greater in mines where the intake opening is a slope or drift, since in this

case the upcast column is balanced by an outside air column, whose temperature is affected by the change to a greater extent than would be the case in a downcast shaft column.

QUES. 1140.—What causes the variation of the temperature of the air when it is passing through the mine? Does such change of temperature affect the volume of air passing? Explain fully.

F.—Pa. (*B*)

ANS.—The natural heat of the mine, or of the earth's strata, together with the heat generated by the slow combustion of the fine coal and dust, burning of lamps, and the animal heat of the men and animals, change the temperature of the air-current as it passes through the mine. In winter time, the outside air being colder, its temperature is raised, while passing through the mine airways, by the natural heat derived from the earth. In summer, the reverse is true; the outside air being warmer, its temperature is lowered by passing through the mine airway by the absorption of its heat by the cooler strata with which it comes in contact. It has been found that beyond the depth of 50 ft., the temperature of the earth's strata increases at an average rate of about 1° F. for each 65 ft. of depth. Thus, for a depth of 2,000 ft., the temperature would be $\frac{2{,}000-50}{65}+60 = 90°$ F., assuming the temperature 50 ft. below the surface to be 60° F. The volume of the current varies directly as the absolute temperature of the air; thus, if 50,000 cu. ft. of air is passing per minute in the intake airway, at a temperature of 0° F., and the temperature of the return current, in the same mine, is 60° F., the expanded volume x of the return current will be

$$x = \frac{460+60}{460+0}\times 50{,}000 = \frac{520}{460}\times 50{,}000 = 56{,}521+ \text{ cu. ft. per min.}$$

QUES. 1141.—If the temperature of a mine having a large volume of air circulating through it, is 50° F., and the temperature of the outside atmosphere 80° F., what effect will this difference of temperature have on the airways of the mine?

M.—B. C., Canada

ANS.—The effect of the outside air having a temperature of 80° F., being cooled in the mine to 50° F., will be to deposit a large quantity of moisture in the airways. This effect will be manifested by what is termed the sweating of the roof and timbers of the airway. Since the outside temperature is not always as high as 80° F., but during the night may fall to even less than the temperature of the mine, the result is an alternating dry and moist condition of the airways. This alternate dry and moist condition of the mine air causes the rapid decay of the timber in the airways, often producing a considerable fungus growth on the timber. The cooling of the warm outside air as it enters the mine also has the effect of decreasing the quantity of air circulating in the mine.

QUES. 1142.—A volume of 155,650 cubic feet of air enters a mine at a temperature of 32° F.; what is the volume at the outlet, the temperature being 65° F.? *I.—Pa. (A)*

ANS.—The volume of the expanded air at the outlet will be increased in the proportion of

$$(460+65) \div (460+32);$$

then, $$\frac{525}{492} \times 155{,}650 = 166{,}089+ \text{ cu. ft.}$$

QUES. 1143.—If the anemometer records a velocity of 500 feet per minute in an intake airway having a sectional area of 60 square feet, and the thermometer shows a temperature of 32° F., what will be the volume of air passing in the same airway per minute, when the temperature has risen to 60° F.? *I.—Pa. (B)*

ANS.—The original volume of air passing in the intake airway is $60 \times 500 = 30{,}000$ cu. ft. per min., at a temperature of 32° F. The expanded volume of air, when the temperature has risen to 60° F., is, then,

$$x = 30{,}000 \times \frac{460+60}{460+32} = 30{,}000 \times \frac{520}{492} = 31{,}707+ \text{ cu. ft. per min.}$$

QUES. 1144.—Assuming that there is 30,000 cubic feet of air entering a mine, how will the volume be affected by the temperature being raised 20°, the atmospheric pressure remaining the same? *F.—Pa. (A)*

ANS.—For a constant pressure, the volume of any given weight of air varies as its absolute temperature, or the volume ratio is equal to the absolute temperature ratio; calling the required volume of air x, and assuming the original temperature of the air to be 60° F., the increased temperature being then $60+20 = 80°$ F.,

$$\frac{x}{30{,}000} = \frac{460+(60+20)}{460+60},$$

and $$x = 30{,}000 \times \frac{540}{520} = 31{,}153+ \text{ cu. ft.}$$

QUES. 1145.—The temperature at the inlet airway of a mine is 60° F., and 80,000 cubic feet of air is passing per minute into the mine; what should be the quantity of air at the outlet, if the temperature at that point is 70° F.? *F.—Pa. (A)*

ANS.—For the same weight of air in circulation at the inlet and the outlet, the quantity is proportional to the absolute temperature,

$$\frac{x}{80{,}000} = \frac{460+70}{460+60};$$

or, $$x = 80{,}000 \times \frac{530}{520} = 81{,}538+ \text{ cu. ft. per min.}$$

QUES. 1146.—The inlet air-current of a mine has a temperature of 60° F., and at the outlet the temperature is 65° F., the barometer is 30 inches; what is the difference in the weight of 100 cubic feet of air between the inlet and the outlet? *F.—Pa. (B)*

ANS.—The difference in weight is given by the formula,

$$\text{Diff.} = 100(1.324 \times 30) \times \frac{65-60}{(460+60)(460+65)} = .0727+ \text{ lb.}$$

QUES. 1147.—A current of air entering a mine is 32,000 cubic feet at the inlet, and 34,000 cubic feet at the outlet, what is the cause of the increased quantity? *F.—Pa. (B)*

ANS.—The increase of quantity may be due to either or both of two causes: an increase of the temperature of the air-current in passing through the mine; the diffusion of mine gases into the air-current.

QUES. 1148.—Calculate the volume of air and gas that will escape from a space of 1,000 cubic feet, if the barometer changes from 31 inches to 30 inches, and the temperature from 65° F. to 80° F. *B.—B. C., Canada*

ANS.—For a given weight of air and gas, the volume is always inversely proportional to the barometric pressure and directly proportional to the absolute temperature, then

$$\frac{q_2}{q_1} = \frac{p_1}{p_2} \times \frac{T_2}{T_1};$$

or, substituting the given values, and calling x the expanded volume of air and gas, we have

$$\frac{x}{1{,}000} = \frac{31}{30} \times \frac{460+80}{460+65};$$

whence, $$x = 1{,}000 \times \frac{31}{30} \times \frac{540}{525} = 1{,}062+ \text{ cu. ft.}$$

That is to say, the volume of air and gas that will escape, resulting from this change in barometer and temperature is $1{,}062 - 1{,}000 = 62$ cu. ft.

QUES. 1149.—To find the percentage of mine gases given off by a mine, the air at the inlet was measured and found to be 137,500 cubic feet per minute at a temperature of 61° F., the air at the outlet measured 150,200 cubic feet per minute, at a temperature of 76° F., what is the percentage of mine gases present in the air leaving the mine? *M.—B. C., Canada*

ANS.—The expansion of the volume of the air entering the mine, due to the given rise of temperature, is

$$\frac{460+76}{460+61} \times 137{,}500 = 141{,}459+ \text{ cu. ft. per min.}$$

Subtracting this expanded volume from the total volume of air measured in the outlet, the actual volume of mine gases is

$$150{,}200 - 141{,}459 = 8{,}741+ \text{ cu. ft. per min.}$$

The percentage of mine gas in the return air is therefore

$$\frac{8{,}741}{150{,}200} \times 100 = 5.8+ \text{ per cent.}$$

CHAPTER XIII

MINE FANS

GENERAL PRINCIPLES AND CONSTRUCTION OF FANS

QUES. 1200.—Describe the principles on which a mine fan operates and does its work. *F.—Pa. (A)*

ANS.—Most mine fans operate on the principle of centrifugal force, producing a depression at the intake or central orifice and a compression at the circumference of the fan. Air is thus drawn into the fan at the center and expelled at the circumference by the action of the centrifugal force developed by the revolution of the air contained in the fan.

QUES. 1201.—Explain the principle of a ventilating fan and state what conditions of the mine will enter into your calculations of the diameter and width of the fan. *I.—Pa. (B)*

ANS.—The principle of a centrifugal ventilating fan may be stated as follows: The centrifugal force developed by the revolution of the weight of air within the fan blades produces a depression within the fan and an excess of pressure at the circumference. As a result, air is drawn in at the central orifice and thrown out at the circumference. By connecting the intake and discharge openings of the fan, the one with the fan drift leading to the mine, and the other with the atmosphere, a circulation of air in and through the mine is established. The conditions of the mine that determine the size of the ventilator are: The relation of the quantity of air in circulation to the unit of ventilating pressure, and the sectional area of the fan drift, which determines the velocity of the current in the fan drift.

QUES. 1202.—Describe the ventilating fan. What are the advantages and disadvantages of driving a fan by a belt? In what respects is a fan superior to a furnace as a ventilator? *F.—Pa. (A)*

ANS.—A mine ventilating fan consists of a central shaft to which are attached radiating arms supporting the blades. These blades are made straight or curved forwards or backwards; in some fans, vanes shaped like a propeller blade are used. The whole mechanism is rotated either by a

direct-connected steam engine or by a belt connecting the pulley on the fan shaft with the engine. The fan is placed between the walls or casings having central openings for the air to enter, but the circumference of the fan may be either enclosed or open.

The advantage of a belt-driven fan is that the fan can be driven at a higher velocity than the engine, and, as a rule, runs more smoothly. The disadvantages are those common to all belt-driven machines, such as loss of power due to the slip of the belt, the wear of the belt, etc.

The fan is superior to the furnace in mine ventilation, because it is not as much affected by changes in atmospheric pressure; and the circulation is more easily controlled in the mine, and it costs less for fuel and attendance.

DIMENSIONS OF MINE FANS

QUES. 1203.—In the selection of mine fans, what rule would guide you in determining the width and diameter of the fan and the area of the fan inlet? *I.—Pa. (B)*

ANS.—The best rule for this purpose is to make the intake area sufficient to pass the required quantity ot air at a velocity varying from 1,000 to 1,500 ft. per min., or 1,200 ft. per min. for an average intake velocity. Then, for double-intake fans make the breadth of the fan five-eighths of the diameter of the intake opening. This will provide an area at the throat of the fan slightly greater than the total area of the intake openings, which is necessary on account of the slight reduction of velocity at this point owing to shock and change of direction of the air-current. For single-intake fans, make the breadth of the fan five-sixteenths of the diameter of the intake opening. Having determined the diameter of the intake opening and the width of the fan, its outer diameter is determined from the required depth of the fan blades. In other words, the fan must be built up from its intake opening to the circumference. The depth of the fan blades is a factor that must be proportionate to the resistance against which the fan is to operate. The ratio of the outer diameter of the fan to the inner diameter is sometimes determined by the formula

$$m = \frac{D}{d} = \sqrt[3]{\frac{\sqrt{a}\,Q}{n^2}c + \left(\frac{3{,}000}{X}\right)^2 + 1},$$

in which m = ratio of outer to inner diameter $\left(m = \frac{D}{d}\right)$;

Q = quantity of air in circulation, in cubic feet per minute;

a = sectional area of fan drift where power on the air is measured, in square feet;

n = speed of rotation fan, in revolutions per minute;

c = fan constant, ordinarily c = 4 to 6;

$X = \sqrt[3]{\frac{Q^2}{p}}$.

The value of the fan constant c will vary according to the style of the fan and its construction with respect to the amount of resistance offered to the passage of the air through the fan, but in general this value may be assumed as varying from $c = 4$ to $c = 7$. The more obstructed the intake area or the greater the resistance to the flow of air through the fan, the higher will be the value of this constant. In using this formula, it is important to determine, by experiment, the proper constant corresponding to the conditions for which the fan is designed. The outer diameter of the fan D, and the expansion of the spiral casing e at the point of cut-off are then determined by the formulas

$$D = m\,d,$$

$$e = \frac{Q}{\pi\, D\, n\, b},$$

in which b = breadth of fan blade.

Murgue's method of determining the outer diameter of a fan employs the formula

$$h = \frac{u^2}{g},$$

in which h = head of air column, in feet;
u = tangential speed or tip speed of the fan, in feet per second;
g = force of gravity (32.16).

Or, expressed in terms of the water gauge, the tip speed that will produce a given water gauge i, is (with a temperature of 62° F. and a barometer reading of 30 in.) $u = 46.8\sqrt{i}$. From the tip speed so determined, the diameter of the fan is calculated according to the speed of rotation n, by the formula

$$D = \frac{60\,u}{\pi\; n}$$

This method, however, does not take into account the width of the fan blades, or make any distinction between a small fan running at a high speed or a large fan running at a comparatively low speed of rotation; and in these respects does not allow of the complete adaptation of the fan to its work.

A common rule of thumb makes the outer diameter of the fan twice the inner diameter. Although this rule has been widely used, it does not, of course, consider any of the conditions that should properly be considered in the design of a fan. The following approximate formulas are also used for diameter of intake and breadth of blade:

Diameter of intake opening of single intake fans,

$$d = \tfrac{1}{35}\sqrt{Q}$$

Breadth of fan blades of single intake fans,

$$b = \tfrac{1}{3}\,d$$

Diameter of intake opening of double intake fans,

$$d = \tfrac{1}{45}\sqrt{Q}$$

Breadth of fan blades of double intake fans,

$$b = \tfrac{5}{8}\,d$$

QUES. 1204.—A fan is designed to produce a current of 175,000 cubic feet of air per minute; what should be the diameter of its central orifice if it receives its air upon each side? *F.—Pa. (A)*

ANS.—The velocity at the intake or central orifice of a fan should not exceed 1,200 or 1,500 ft. per min.; hence, in all fans having double-intake orifices, or which receive the air upon both sides,

$$\frac{175,000}{2\times 1,200} = 72.917 \text{ sq. ft., area of one orifice;}$$

$$\sqrt{\frac{72.917}{.7854}} = 9.635 \text{ ft., say 9 ft. 8 in.}$$

Or, using the approximate formula given in the preceding question,

$$d = \tfrac{1}{40}\sqrt{Q} = \tfrac{1}{40}\sqrt{175,000} = 10.4 \text{ ft.}$$

QUES. 1205.—If 40,000 cubic feet of air is to be delivered per minute, what should be the diameter of the port of entry of a fan, there being two ports? What should be the width of the fan blade? *I.—Ia.*

ANS.—It is customary to assume a velocity for the air entering the fan, varying from 1,000 to 1,500 ft. per min. The fan taking air upon both sides, the quantity of air passing one port is 40,000 ÷ 2 = 20,000 cu. ft. per min., and for the area of this port of entry, 20,000 ÷ 1,200 = 16.67 sq. ft. The diameter of a circle having this area is

$$d = \sqrt{\frac{16.67}{.7854}} = 4.6 \text{ ft.}$$

In calculating the breadth of the fan blade, it must be remembered that all the air passing into the fan through the two ports of entry must pass through the area of the throat of the fan, which is the cylindrical surface of an imaginary cylinder whose bases are the two ports of entry, the length of the cylinder being the breadth of the fan blade. At the throat of the fan, the velocity of the air is somewhat less than the entering velocity, say .8 of the entering velocity. The intake area should then be .8 of the throat area, giving the equation for double-intake fans (two ports),

$$2(.7854\, d^2) = .8(3.1416\, d \times b);$$

whence $b = \frac{5}{8}\, d;$

or, in this case, $b = \frac{5}{8} \times 4.6 = 2.875$ ft.

It has been assumed by some authors that there is no reduction of velocity at the throat of the fan, and the breadth of the fan has then been made one-half of the intake diameter, but this gives a contracted throat resulting in an intake eddy destroying the efficiency of the fan.

QUES. 1206.—If the efficiency of the fan is 70 per cent., what size fan will be required to circulate 45,000 cubic feet of air per minute under a ½-inch water gauge? *I.—Pa. (B)*

ANS.—One method of calculating the size of fan required to produce a given circulation is by the use of the formula

$$h = K\frac{v_t^2}{g} \qquad (1)$$

in which h = head of air column producing circulation, in feet;
K = manometrical efficiency of fan;
v_t = tangential velocity of blade tips, in feet per second;
g = force of gravity, 32.16 feet per second.

Or, reducing the feet of air column to inches of water gauge, the ratio of the weight of air to weight of water being $\frac{1.2}{1,000}$,

$$i = K\frac{v_t^2}{g}\,\frac{1.2\times 12}{1,000} \qquad (2)$$

in which, beside the symbols given above,
i = water gauge producing circulation, in inches

Solving formula 2 with respect to v_t, the tangential velocity required to produce the water gauge i is

$$v_t = 47.26\sqrt{\frac{i}{K}} \qquad (3)$$

Substituting the given values in formula 3,

$$v_t = 47.26\sqrt{\frac{.5}{.70}} = 39.94, \text{ say } 40 \text{ ft. per sec.}$$

Assuming a speed of 100 rev. per min., the diameter of the fan that will yield this tangential speed is

$$d = \frac{40\times 60}{100\times 3.1416} = 7.64 \text{ ft.}$$

This method always assumes an efficiency less than 50 per cent., and hence taking the efficiency as 70 per cent., gives a diameter much too small; also, it does not afford any opportunity for calculating the width or depth of the blade.

The size of fan required may be calculated by means of the formulas given in answer to Ques. 1203.

Substituting the given values in these formulas, assuming for the area of fan drift a = 50 sq. ft., and for the fan constant c = 4,

$$X = \sqrt[3]{\frac{q^2}{p}} = \sqrt[3]{\frac{45,000^2}{.5\times 5.2}} = 920;$$

$$m = \sqrt[3]{\frac{\sqrt{50\times 45,000}}{100^2}\times\left[4+\left(\frac{3,000}{920}\right)^3\right]} + 1 = 1.9$$

For a double intake fan,

$$d = \tfrac{1}{40}\sqrt{45,000} = 5.3 \text{ ft.}$$
$$b = \tfrac{5}{8}\times 5.3 = 3.3 \text{ ft.}$$
$$D = 1.9\times 5.3 = 10.07, \text{ say } 10 \text{ ft.}$$
$$e = \frac{45,000}{3.1416\times 10\times 100\times 3.3} = 4.34 \text{ ft.}$$

FAN CASING AND CHIMNEY

QUES. 1207.—How should the outlet to an exhaust fan be arranged so as to allow the air from the mine to be discharged freely? *F.—Ind.*

ANS.—An exhaust fan when running in a closed casing, or what is called a close-running fan, should have the casing surrounding the periphery of the fan of a spiral form. This casing should begin to expand at a point about the distance between two consecutive blade tips from the cut-off, and should continue to expand uniformly, in the direction of revolution, all the way around the circumference of the fan to the cut-off. The amount of this expansion should be calculated for each particular fan by the formula for calculating the expansion, given in reply to Ques. 1203. At the point of cut-off, the spiral conduit surrounding the fan should connect with the expanding chimney or outlet, whose height should be at least greater than one-half the diameter of the fan.

QUES. 1208.—What advantage is derived from the use of the expanding chimney in a ventilating fan? *M.—Ill.*

ANS.—The expanding or évasé chimney is used when a fan is exhausting air from the mine and discharging it through the chimney into the atmosphere. The chimney is made expanding so as to reduce the velocity of the air discharged into the atmosphere, resulting in a saving of power.

QUES. 1209.—The area of a discharge opening of a fan is 5 ft. × 5 ft.; the quantity of air passing through the fan is 50,000 cubic feet per minute. What theoretical effect will be produced by building on the opening a chimney that will gradually expand until the dimensions of the discharge will be 10 ft. × 10 ft.? *M.—Ill.*

ANS.—The power lost by discharging air at a high velocity, varies as the square of the velocity of the discharge. In this case, the area at the point of discharge is increased four times, and as a consequence the velocity is reduced in the same proportion; in other words, the velocity of discharge is made one-fourth of the previous velocity and the horsepower lost is reduced to one-fourth squared, or one-sixteenth of the previous loss.

THEORETICAL WATER GAUGE

QUES. 1210.—What is the theoretical water gauge due to a periphery speed of 3,600 feet per minute, by a Guibal fan 20 feet in diameter, the density of water to that of air being taken as 1,000 to 1.2? *I.—Pa. (A)*

ANS.—The theoretical water gauge due to this speed of the fan is found as follows: The speed of the blade tips is 3,600 ÷ 60 = 60 ft. per sec. Then,

$$I = \frac{u^2}{g} \times \frac{12 \times 1.2}{1,000} = \frac{60^2}{32.16} \times \frac{12 \times 1.2}{1,000} = 1.6+ \text{ in.},$$

in which I = water gauge, in inches;
g = force of gravity (32.16 at sea level).

QUES. 1211.—What pressure, measured by the water gauge, should a theoretically perfect fan, 10 feet in diameter, make at a speed of 70 revolutions per minute, when running in a closed space? *M.—Ill.*

ANS.—The formula in common use for determining the theoretical water gauge produced by a fan running at a fixed speed, at sea level, is

$$I = \frac{v_t^2 \times 12 \times 1.2}{g \times 1,000},$$

in which v_t = tangential speed of fan, in feet per second.

Applying this formula,

$$I = \left(\frac{3.1416 \times 10 \times 70}{60}\right)^2 \times \frac{12 \times 1.2}{32.16 \times 1,000} = .6015$$

This is the theoretical water gauge of this fan when delivering air; the actual water gauge will probably be somewhat less than one-half of this amount, since by the use of this formula no fan can present a higher manometrical efficiency than 50 per cent.

The static water gauge or the water gauge produced when the fan, running at a given speed, is discharging into a closed space, may be determined by the formula

$$p_s = \frac{2g}{v} \times i$$

in which p_s = static water gauge;
i = actual water gauge.

For example, a 12.5 ft. × 10 ft. fan produced a volume of practically 300,000 cu. ft. of air per min. under a water gauge of 3.1 in., at a speed of 200 rev. per min. Assuming an area of the airway about 150 sq. ft., the velocity of the air-current would be 2,000 ft. per min., or about 35 ft. per sec. Under these conditions, applying the formula, the static gauge due to the action of this fan is

$$p_s = \frac{2 \times 32.16}{35} \times 3.1 = 5.697 \text{ in.}$$

In the actual test of the fan when the fan was closed as tightly as possible, the water gauge gave a reading of 5.6 in.

EFFICIENCY OF A FAN

QUES. 1212.—What do you understand by manometric efficiency as relating to fans? What is the manometric efficiency of a fan producing 2.5 inches of water gauge, the blowing-in pressure being 2.3 pounds per square foot; and the blowing-out pressure 5.7 pounds per square foot? *I.—Ia.*

ANS.—The term *manometrical efficiency* as relating to fans is the ratio that the effective pressure bears to the theoretical pressure calculated by the formula,

$$I = \frac{v_t^2}{g}\,\frac{w}{5.2},$$

in which I = theoretical water gauge, in inches;
v_t = velocity of blade tips, in feet per second;
g = force of gravity (32.16 at sea level);
w = weight of 1 cubic foot of air.

The meaning of this question is evidently that the loss of pressure in the fan is $2.3+5.7 = 8$ lb. The effective pressure corresponding to 2.5 in. of water gauge is $2.5\times 5.2 = 13$ lb. The efficiency in this case is

$$\frac{13}{13+8}\times 100 = 61.9 \text{ per cent.}$$

This, however, is a wrong use of the term manometric efficiency, which expresses in percentage the ratio of the effective water gauge 2.5 in. to the theoretical water gauge calculated by the formula just given. To calculate the theoretical water gauge, it is necessary to know the tip speed of the fan and the density of the air and the force of gravity.

QUES. 1213.—Explain how you would proceed to determine the efficiency of a ventilating fan. *I.—Pa. (A)*

ANS.—To calculate the manometrical efficiency of a ventilating fan, the theoretical water gauge I due to the fan's action is first obtained from either of the following expressions:

$$I = \frac{v_t^2\,w}{g\,5.2} = .255\,\frac{v_t^2\,B}{g\,460+t} = .52\,\frac{v_t^2\,p}{g\,460+t},$$

in which I = theoretical water gauge, in inches;
v_t^2 = velocity of blade tips, in feet per second;
g = force of gravity (32.16 at sea level);
w = weight of 1 cubic foot of air weighing .0766 lb. at a temperature of 60° F. and a barometric pressure of 30 in.;
B = barometer reading, in inches;
t = temperature of air, in degrees Fahrenheit;
p = atmospheric pressure, in pounds per square inch.

The efficiency is then determined from the formula

$$K = \frac{i}{I} \times 100,$$

in which K = efficiency of ventilator;
i = actual water gauge, in inches.

For example, to find the efficiency of a ventilating fan, 20 ft. in diameter, making 70 rev. per min., and giving a water gauge of 2 in., the speed of the blade tips is

$$v_t = \frac{70(3.1416 \times 20)}{60} = 73.3+ \text{ ft. per sec.}$$

Then, using the first of the formulas given, the theoretical water gauge due to this fan, at the given speed, is

$$I = \frac{73.3^2}{32.16} \times \frac{.0763}{5.2} = 2.45 \text{ in.}$$

Then, $$K = \frac{2}{2.45} \times 100 = 81.6 \text{ per cent.}$$

If it is desired to find the mechanical efficiency (the ratio between the effective and theoretical work performed), the usual practice is to take a card from the engine running the fan and calculate from it the power employed, and then divide the effective work per minute $q\,p$ in the fan drift, by the power employed, and multiply the quotient obtained by 100; the result is the percentage of efficiency. This method embraces in the efficiency of the fan that of the engine, and does not therefore present a correct basis of comparison between different fans.

QUES. 1214.—Describe the several forms of centrifugal ventilating fans, and state how you would proceed to determine the efficiency of each. Also, give your opinion as to the advantage of a forcing fan over an exhaust fan under certain conditions.

I.—Pa. (A)

ANS.—The two general forms of centrifugal fans are the open-running and the closed-running, or enclosed fan. The open-running fan is being rapidly given up, a few fans of the Waddle type being about the only remaining representatives of this class of ventilators. The open-running fan can only exhaust air from a mine; the closed fan may be either an exhaust fan or a blowing fan. When the fan is blowing the air into the mine, the outside air is drawn into the fan through the central openings and forced by the fan's action toward the circumference, passing into the fan drift and thence into the mine airways. When exhausting, the fan is housed and an arrangement of doors is made to connect the intake, or central orifice of the fan, with the fan drift, while the discharge from the fan is conducted into an expanding chimney instead of into the fan drift as before. The manometrical efficiency of a fan is the percentage of its theoretical pressure that becomes effective in the mine airways and is determined for any form of fan as was explained in the answer to the preceding questions.

The advantage of the force fan over the exhaust is found chiefly in the ventilation of non-gaseous workings, where the main haulage roads may be

made the return airways. In the use of the force fan, in this case, no door is required on the main haulage road at the shaft bottom. An exhaust fan here would require the use of double doors on the main road at the shaft bottom. Another advantage of the force fan over the exhaust is found in the fact that in compressive ventilation the airways are ventilated under a pressure above that of the atmosphere, and, as a consequence, the gases generated in the old workings of a mine are driven back and are often forced out through some other opening into the atmosphere, without being brought into the passageways of the mine. Still another advantage lies in the fact that the fan is often more efficient when working on the cold outside air than when working on the warmer air of the mine, as it does when exhausting. This advantage, however, may be reversed in the summer season or when the mine air is heavy with blackdamp.

QUES. 1215.—What is the general efficiency of a fan? If the horsepower of an engine is 40 and the water gauge 1.5 inches, what quantity of air will you expect to get? *F.—Pa. (B)*

ANS.—By the *general efficiency* of a fan is commonly understood the ratio of the effective work on the air to the indicated power of the engine. This is often called the *mechanical efficiency* of the fan, although including the efficiency of the engine. The efficiency of ventilating fans varies much. For an ordinary fan, the mechanical efficiency may be stated as, say, 60 per cent. of the rated horsepower of the engine. Under favorable conditions, especially if the fan is proportioned to the work which it is performing, an efficiency of 80 per cent. of the horsepower of the engine is at times obtained. Assuming an efficiency of 60 per cent., if the engine is rated at 40 horsepower, the horsepower effective upon the air will be $40 \times .60 = 24$ H. P. Then if the water-gauge reading is 1.5 in., the quantity of air in circulation is given by the formula

$$q = \frac{u}{p} = \frac{24 \times 33{,}000}{1.5 \times 5.2} = 101{,}538 \text{ cu. ft. per min.}$$

QUES. 1216.—With a fan of 30 horsepower, from which you are obtaining only 50 per cent. useful effect while the water gauge stands at 2.3 inches, what quantity of air per minute should you get? *I.—Ia.*

ANS.—Since there is 50 per cent. of useful effect in this case, the horsepower effective on the air is $30 \times .50 = 15$ H. P. The quantity of air this power will pass, under a water gauge of 2.3 in., is

$$q = \frac{u}{p} = \frac{15 \times 33{,}000}{2.3 \times 5.2} = 41{,}388+ \text{ cu. ft. per min.}$$

QUES. 1217.—If the indicated horsepower of an engine operating a fan is 40, while the horsepower of the air is only 28, what is the percentage of useful effect of the engine? *I.—Ia.*

ANS.—The percentage of useful effect of the engine and fan is calculated as follows:

$$\frac{28}{40} \times 100 = 70 \text{ per cent.}$$

This is the mechanical efficiency of the engine and ventilator combined.

QUES. 1218.—In a colliery at which there are two fans, a blower and an exhaust fan, working under apparently similar conditions, though producing different results, show the successive steps you would take in determining which is the better fan. *F.—Pa. (A)*

ANS.—The superiority of one fan over another fan in mining work is determined by the quantity of air circulated per horsepower by each in the same airway. In comparing two fans operating on different circulations, to ascertain their relative efficiencies, it will be necessary to reduce their circulations to a common basis of ventilating pressure per horsepower, the efficiency of the ventilator being expressed by the formula

$$K = \frac{Q\,p}{U},$$

in which K = efficiency of fan;
Q = quantity of air in circulation, in cubic feet per minute;
p = ventilating pressure, in pounds per square foot;
U = power applied to fan shaft.

By ascertaining the quantity of air in circulation, the ventilating pressure, and the power applied to the fan shaft or the power developed in the steam cylinder, as calculated from an indicator card, in each case, and substituting these values in the formula, the efficiency of each fan can be calculated and their work compared on an equal basis. The fan showing the higher efficiency is ordinarily the better fan.

FORCE FANS AND EXHAUST FANS

QUES. 1219.—Explain the difference in the construction of a force fan and an exhaust fan. *F.—Pa. (A)*

ANS.—The difference consists only in a different housing. Every fan should be built so that it may be used either as an exhaust fan or a force fan, as the circumstances may require. Both of these types of fan agree in the following points: The air is admitted at the central orifice or eye of the fan and travels radially from the center to the circumference. At the circumference of the fan, it enters the spiral conduit surrounding the fan and is carried to the fan drift or to the chimney, as the case may be. Thus far, the action and the arrangement of the two types of fan are identical.

In the exhaust fan, the doors at the central orifice opening to the atmosphere are closed and other doors are opened to connect the eye of the fan

with the fan drift leading to the mine. The air supplied to the fan is thus drawn from the mine. After traversing the fan, this air is thrown out through the chimney into the atmosphere. This construction requires a housing over the fan shaft covering the intakes of the fan and connecting them with the mine.

In the force fan, the doors at the central orifice of the fan are opened, thus giving free access to the atmospheric air, which is drawn into the fan and discharged therefrom into the mine. Fig. 1 shows the arrangement of the doors which control the passage of the air-current. The full lines A, A show the position of the doors in the fan drift C when the fan is forcing air into the mine. The fan now draws its air from the atmosphere and discharges it into the fan drift, as indicated by the arrow B. On the other hand, when the fan is exhausting, these doors are thrown back, inwards, as shown by the dotted lines A', A'. This establishes direct connection between the mine and the intake openings of the fan by means of

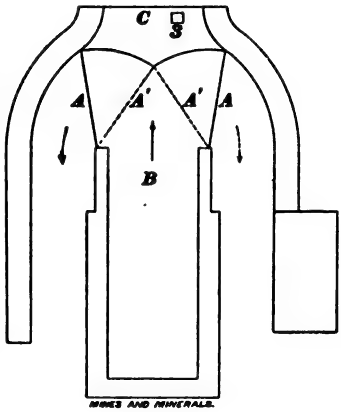


FIG. 1

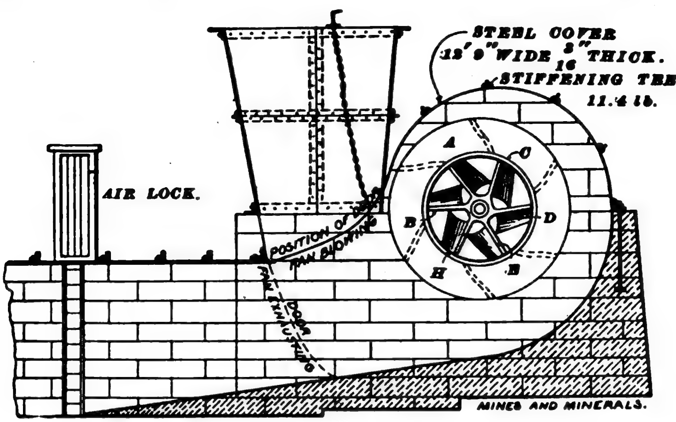


FIG. 2

the housing that covers them. The fan now draws the air from the mine through the fan drift C and past the doors A', A' into the fan. This air, after passing through the fan, is discharged from the circumference through a door into the évasé chimney and hence into the atmosphere. Fig. 2 is an elevation of the fan showing position of doors both for blowing and exhausting.

QUES. 1220.—In case of a fire, if it became necessary to change an exhaust fan into a force fan, how would you do so? *F.—Pa.* (*A*)

Ans.—By reversing the fan and changing the doors, as explained in the preceding question.

Ques. 1221.—Which is the more effective, the exhaust or forcing fan? Give your reasons. *F.—Pa. (A)*

Ans.—Neither of these types of fan can be considered as being more effective than the other, at all times, each being adapted to different conditions, and each being equally effective under those conditions to which it is adapted. The exhaust fan used in ventilating a mine on the vacuum or exhaust system is generally the more effective fan in the ventilation of a gaseous seam. On the other hand, the force fan used in ventilating a mine on the plenum system is a more effective fan to use in the ventilation of a large non-gaseous mine, especially when there are large standing areas or abandoned workings that give off much mine gas. If an exhaust fan instead of a force fan were used under these conditions, the gases from the abandoned workings would be drawn into the mine instead of being forced out through the cracks and crevices of the strata and escaping to the surface. In a gaseous mine, it is generally desirable that the haulage be performed on the intake airway, and it is then necessary to use the exhaust fan to avoid the necessity of placing double doors on the main haulage road. Aside from these conditions in the mine, the exhaust fan is as effective as the force fan, except only as its efficiency may at times be impaired by reason of working on the lighter mine air instead of the heavier outside air as in the case of a force fan; but even in this respect the exhaust fan may prove more efficient than the force fan if the air exhausted from the mine and passing through the fan is heavy with blackdamp.

Ques. 1222.—Which should be the larger of the two, the blowing or exhaust fan, to obtain the same result? If you think there should be a difference, give your reasons. *F.—Ind.*

Ans.—Of the two types mentioned the exhaust fan should generally be the larger, for like conditions in the mine, in order to circulate the same quantity of air by the same power. The difference between these two types, however, is small and arises simply from the difference in the density of the air exhausted from the mine and the atmospheric air. The exhaust fan is working upon air subject to a lower pressure than that of the atmosphere, while the blow-down fan is working upon air subjected to a higher pressure than that of the atmosphere. The gaseous condition of the mine air may be such as to increase or decrease its density, according as blackdamp or firedamp prevails in the mine; and an exhaust fan filled with air containing a large percentage of blackdamp may be often more efficient than a blow-down fan, since pure blackdamp, CO_2, is one-half again as heavy as air, while firedamp, on the other hand, may have a density approaching one-half that of air. Since either of these conditions may be present or they may alternate, it is better to provide sufficient fan capacity for the worst condition possible.

QUES. 1223.—When is an exhaust fan to be preferred to a force fan in ventilating a mine? *F.—Ia.*

ANS.—The exhaust fan is generally to be preferred in the ventilation of a gaseous mine, for the reason that in such a mine the haulage is more safely performed on the intake airway; and the use of an exhaust fan avoids the necessity of placing doors on the main haulageway close to the mouth of the mine, or at the bottom of a shaft or slope, as would be necessary if a force fan were used under these conditions.

VOLUME AND PRESSURE OF AIR PRODUCED BY FAN

QUES. 1224.—What pressure and power would be required to produce and maintain an air volume of 150,000 cubic feet per minute, through an airway 8 ft. × 10 ft. and 3,000 feet long, and what would be the total power exerted by the fan engine if 70 per cent. of the power was expended on the air? *I.—Pa. (B)*

ANS.—The pressure per square foot producing circulation is

$$p = \frac{k\,l\,o\,q^2}{a^3} = \frac{.00000002 \times 3{,}000 \times 2(8+10) \times 150{,}000^2}{(8 \times 10)^3} = 95 \text{ lb., nearly.}$$

For the effective horsepower in this case we have

$$H = \frac{Q\,p}{33{,}000} = \frac{150{,}000 \times 95}{33{,}000} = 432- \text{ H. P.}$$

This power on the air being 70 per cent. of the power of the fan engine, the latter is

$$H' = \frac{H}{K} = \frac{468}{.7} = 624+ \text{ H. P.}$$

QUES. 1225.—A fan running at a speed of 50 revolutions per minute produces 60,000 cubic feet of air per minute with a water gauge of 1 inch; how much will the quantity and water gauge be increased by speeding the fan to 80 revolutions per minute? *F.—Pa. (A)*

ANS.—A common rule assumes the quantity of air yielded by a fan as proportional to its speed of rotation, and the pressure to the square of the speed, or, in this case,

$$q = \frac{80}{50} \times 60{,}000 = 96{,}000 \text{ cu. ft. per min.,}$$

and for the pressure,

$$p = \left(\frac{8}{5}\right)^2 \times 1 = 2.56 \text{ in.}$$

As a fact, however, in practice this quantity is not obtained, but the fifth power of the quantity varies as the fourth power of the speed, or the

fifth power of the quantity ratio equals the fourth power of the speed ratio, which gives

$$\left(\frac{q}{60{,}000}\right)^5 = \left(\frac{80}{50}\right)^4;$$

and $$q = 60{,}000\sqrt[5]{\left(\frac{8}{5}\right)^4} = 87{,}388+ \text{ cu. ft. per min.}$$

The water gauge in any circulation varies as the square of the quantity, or the water-gauge ratio equals the square of the quantity ratio, which gives, in this case,

$$\frac{i}{1} = \left(\frac{87{,}388}{60{,}000}\right)^2;$$

and $$i = 2.12 \text{ in}$$

QUES. 1226.—A fan making 50 revolutions per minute gives 4½ pounds pressure per square foot; if the speed is increased to 75 revolutions per minute, what will be the reading of the water gauge? *I.—Ia.*

ANS.—Pressure in any circulation varies as the square of the quantity, and assuming the yield of a fan as being proportional to its speed, it follows that the pressure or water gauge will vary as the square of the speed of the fan; or, in this case,

$$50^2 : 75^2 = \frac{4.5}{5.2} : x; \text{ or } x = \frac{4.5}{5.2}\times\left(\frac{75}{50}\right)^2 = 1.947 \text{ in. water gauge}$$

As a fact, however, the quantity of air does not vary exactly as the speed, nor the pressure as the square of the speed; but, more accurately, the quantity varies as the fifth root of the fourth power of the speed, and the pressure as the fifth root of the eighth power of the same. That is to say, if we double the speed, we do not obtain double the quantity, but about 1.74 times the quantity, and 3 times the pressure. These figures correspond more accurately with the results of practice.

QUES. 1227.—A fan is running at a speed of 60 revolutions per minute with a water gauge of 1 inch, what will be the pressure per square foot if the speed of the fan is increased to 75 revolutions per minute? *F.—Pa. (A)*

ANS.—A water gauge of 1 in. corresponds to a pressure of 5.2 lb. per sq. ft. It is usually assumed that the quantity of air in circulation and the square root of the pressure are proportional to the speed of the fan, or, in other words, the quantity ratio, or the square root of the pressure ratio, is equal to the speed ratio of the fan. Calling the required pressure per square foot x,

$$\sqrt{\frac{x}{5.2}} = \frac{75}{60} = \frac{5}{4} = 1.25;$$

and $$x = 5.2\times 1.25^2 = 8.125 \text{ lb. per sq. ft.}$$

In practice, however, this result is not attained; but the fourth power of the speed ratio is equal to the fifth power of the quantity ratio, or the

eighth power of the speed ratio is equal to the fifth power of the pressure ratio, and then

$$\left(\frac{x}{5.2}\right)^5 = \left(\frac{75}{60}\right)^8 = 1.25^8;$$

and $$x = 5.2\sqrt[5]{1.25^8} = 7.4+ \text{ lb. per sq. ft.}$$

QUES. 1228.—A fan running 60 revolutions per minute gives a water gauge of 2 inches. If the speed of the fan is increased to 90 revolutions per minute, what will be the pressure? If the increased quantity of air is 100,000 cubic feet per minute, what is the horsepower? *I.—Pa. (B)*

ANS.—The pressure due to 2 in. of water gauge is $2\times 5.2 = 10.4$ lb. per sq. ft. Assuming that the quantity is proportional to the speed of the fan, and the pressure to the square of the speed, we have

$$x = 10.4\left(\frac{90}{60}\right)^2 = 23.4 \text{ lb. per sq. ft.}$$

The horsepower required for the circulation of 100,000 cu. ft. of air per minute under this pressure would be

$$H = \frac{q\,p}{33{,}000} = \frac{100{,}000\times 23.4}{33{,}000} = 70.909 \text{ H. P.}$$

Or, assuming the pressure to vary as the fifth root of the eighth power of the speed, which conforms more closely to the results of practice, we obtain for the pressure at 90 rev. per min.,

$$p = 10.4\sqrt[5]{\left(\frac{90}{60}\right)^8} = 10.4\sqrt[5]{1.5^8} = 19.9 \text{ lb. per sq. ft.}$$

and for the horsepower,

$$H = \frac{100{,}000\times 19.9}{33{,}000} = 60.3 \text{ H. P.}$$

QUES. 1229.—If a fan making 100 revolutions per minute produces 40,000 cubic feet of air, how much air should the same fan produce when its speed is increased to 125 revolutions per minute? *F.—Ia.*

ANS.—It is usually assumed that the quantity of air in circulation is in proportion to the number of revolutions the fan makes per minute. By this rule, the quantity of air produced by this fan, at a speed of 125 rev. per min., will be

$$\frac{125}{100}\times 40{,}000 = 50{,}000 \text{ cu. ft.}$$

In practice, this amount will hardly be realized. The quantity of air is more nearly in proportion to the fifth root of the fourth power of the number of revolutions per minute; or, in this case,

$$q = 40{,}000\sqrt[5]{\left(\frac{125}{100}\right)^4} = 40{,}000\sqrt[5]{1.25^4} = 47{,}818 \text{ cu. ft.}$$

QUES. 1230.—Provided you need to increase the quantity of air in a mine without changing the conditions of the airways, in what proportion must pressure and speed of fan be increased?

F.—Pa. (A)

ANS.—First write the formula for pressure in terms of the quantity and of the airway; thus,

$$p = \frac{k s q^2}{a^3}$$

For the same airway $\frac{k s}{a^3}$ is constant, and hence p varies as q^2; or the ratio between the pressures is equal to the square of the ratio between the quantities; or,

$$\frac{p_2}{p_1} = \left(\frac{q_2}{q_1}\right)^2$$

It is customary to assume that the speed of rotation of the fan is proportional to the quantity of air delivered, or the ratio between speeds, in fan ventilation, is equal to the ratio between the quantities; and calling n the number of revolutions of the fan per minute,

$$\frac{n_2}{n_1} = \frac{q_2}{q_1}$$

More correctly, however, the fourth power of the speed varies as the fifth power of the quantity, and

$$\left(\frac{n_2}{n_1}\right)^4 = \left(\frac{q_2}{q_1}\right)^5$$

QUES. 1231.—If a fan should double its speed, what increase would there be in the ventilating pressure, and in what proportion would the quantity of air be increased? *F.—Pa. (A)*

ANS.—When the speed of a fan is doubled, other things being the same, there is obtained about 1.74 times the quantity and about 3 times the pressure, as explained in answer to Ques. 1226.

QUES. 1232.—If in a mine where 100,000 cubic feet of air is passing per minute the water gauge is 1.6 inches, the horsepower of the engine being 50, and the revolutions of the fan 50, what will be the quantity of air, revolutions of the fan, and horsepower of the engine if the water gauge is increased to 3.6 inches?

I.—Pa. (B)

ANS.—The question does not state the cause of the increase of water gauge. This may be the result of an increase of power applied, as when the speed of the fan is increased by an increase of power; or the increase of the water gauge may result from an increased resistance in the airway due to a fall of roof causing a contraction of the sectional area of the

airway, or from a considerable lengthening of the air-courses in the development of the mine or otherwise. The two cases are essentially different.

First Case.—Assuming the increase of water gauge to be due to an increase of the power applied, and assuming the efficiency of the ventilator as constant, the quantity of air in circulation is proportional to the square root of the pressure, and

$$q_2 = q_1\sqrt{\frac{p_2}{p_1}} = 100{,}000\sqrt{\frac{3.6}{1.6}} = 150{,}000 \text{ cu. ft. per min.}$$

As a fact, the efficiency of the motor is decreased as the volume of air passing is increased, and for this reason the increased quantity will be somewhat less than this amount in fan ventilation.

The yield of the fan is often assumed to be proportional to the speed of rotation, which gives

$$n_2 = n_1\frac{q_2}{q_1} = 50\times\frac{150}{100} = 50\times 1.5 = 75 \text{ rev. per min.}$$

This ratio, however, is never realized in practice, but the fifth power of the ratio of the quantity equals the fourth power of the ratio of the speed, or, in this case, since the ratio of the quantity is $\frac{150}{100} = 1.5$,

$$n_2 = n_1\sqrt[4]{1.5^5} = 83 \text{ rev. per min.}$$

for a constant efficiency of the ventilator. As previously stated, however, the efficiency of the ventilator is decreased owing to the increased circulation, and the increased speed will, therefore, be somewhat greater than 83 rev. in actual practice, say 85 rev. per min.

The horsepower being proportional to the cube of the quantity of air in circulation, assuming a constant efficiency of the ventilator,

$$h_2 = h_1\left(\frac{q_2}{q_1}\right)^3 = 50\times\left(\frac{150}{100}\right)^3 = 50\times 1.5^3 = 168.75 \text{ H. P.}$$

But owing to the decreased efficiency, as stated, the required power will be somewhat greater than this amount.

Second Case.—Assuming a constant power applied, as is the case when the increase of water gauge is due to an increased resistance in the airway, the quantity of air in circulation is inversely proportional to the pressure, and

$$q_2 = q_1\frac{p_1}{p_2} = 100{,}000\times\frac{1.6}{3.6} = 44{,}444+ \text{ cu. ft. per min.}$$

In this case (power constant), for a constant efficiency of the ventilator, the speed of rotation of the fan increases with the fourth root of the pressure per square foot, in the airway, and

$$n_2 = n_1\sqrt[4]{\frac{p_2}{p_1}} = 50\sqrt[4]{\frac{3.6}{1.6}} = 61.24+ \text{ rev. per min.}$$

Here, however, the efficiency of the motor is increased owing to the decrease in the quantity of air passing, and as a result the increase in speed is less than that given above, or, say, 55 rev. per min. The power in this case, as assumed before, remains constant (50 H. P.).

QUES. 1233.—With a 38-horsepower fan, we are producing 100,000 cubic feet of air per minute; how many cubic feet will we get from a 30-horsepower fan in the same airway? *M.—Ill.*

ANS.—Assuming like efficiencies of these two fans, and calling the required quantity x; since the quantity varies as the cube root of the power, or the quantity ratio is equal to the cube root of the power ratio,

$$\frac{x}{100{,}000} = \sqrt[3]{\frac{30}{38}};$$

and, $x = 100{,}000\sqrt[3]{.78947} = 92{,}422+$ cu. ft. per min.

QUES. 1234.—At a certain mine, it is proposed to erect a 14-foot fan in place of the furnace in use at present—the quantity of air is 120,000 cubic feet, with water gauge 1.5 inches. Give the revolutions per minute required for this fan to circulate the same quantity of air with the same water gauge. *M.—B. C., Canada*

ANS.—The method in common use for determining the speed of rotation or the number of revolutions of the fan per minute employs the formula

$$I = \left(\frac{\pi D n}{60}\right)^2 \times \frac{1}{g} \times \frac{w}{5.2}$$

or, assuming for normal atmospheric conditions at sea level $w = .0763$, we have, approximately,

$$n = 900\frac{\sqrt{I}}{D}$$

In these formulas n = speed of rotation of the fan, in revolutions per minute;
D = outer diameter of the fan, in feet;
g = force of gravity (32.16);
I = theoretical water gauge, in inches;
w = weight of 1 cu. ft. of air at the assumed temperature and pressure.

Assuming a manometrical efficiency of 50 per cent., the theoretical water gauge in this case is $I = 1.5 \div .5 = 3$ in., and substituting the given values in the formula, the required speed is

$$n = 900\frac{\sqrt{3.0}}{14} = 111+ \text{ rev. per min.}$$

It must not be supposed from this solution that a 14-ft. fan running at a speed of 111+ rev. per min. will produce a water gauge of 1.5 in. irrespective of the conditions of resistance in the airway into which the fan is discharging its air. For example, if this fan is made to do service at another mine where the conditions of resistance are different, it will give a different water gauge and quantity at the same speed. This amounts to the same thing as saying that the fan will present a different efficiency for each circulation.

QUES. 1235.—If one ventilating fan produces 25,000 cu. ft. of air per minute, what total quantity of air per minute will be given if another fan be added to it having the same dimensions and run by the same power? *M.—B. C., Canada*

ANS.—In this case, the total power applied is doubled. Assuming that the efficiencies of the ventilators remain constant, the power on the air is also doubled. But the quantity of air circulated in the mine will vary as the cube root of the total effective powers, or, in this case,

$$x = 25{,}000\sqrt[3]{2} = 31{,}498 \text{ cu. ft. per min.}$$

As a matter of fact, however, the efficiency of the ventilators is increased, since only one-half of this air, or 15,749 cu. ft. is passing through each ventilator under an increased ventilating pressure, resulting in a considerable decrease in the loss of power in the ventilator. We may, therefore, expect a somewhat larger quantity of air than the amount just calculated when the two fans are working together.

EQUIVALENT ORIFICE

QUES. 1236.—What is meant in the science of mine ventilation by the term equivalent orifice? *I.—Ia.*

ANS.—In mine ventilation, the resistance offered by the mine to the passage of a ventilating current is often compared to the resistance offered to the flow of air through an orifice in a thin plate. In each case, the velocity of the flow is proportional to the square root of the pressure or head that produces the flow. The expression for the velocity of any fluid under a certain head h is given by the equation $v = \sqrt{2\,g\,h}$, or since

$$v = \frac{q}{a}, \quad q = a \times \sqrt{2\,g\,h};$$

and introducing the coefficient (.615) for the vena contracta or the contraction in the flow through an orifice in a thin plate,

$$q = .615\,a\sqrt{2\,g\,h}$$

This can be reduced to inches i of water gauge, thus, $h = \dfrac{1{,}000}{1.2 \times 12} \times i.$

Substituting this in the formula, and solving with respect to a, after reducing,

$$A = \frac{.00038 \times q}{\sqrt{i}}$$

This formula gives the value of what is termed the *equivalent orifice* of a mine. It is .00038 times the ratio between the quantity of air in circulation and the square root of the water gauge producing the circulation. It is, in fact, the size of orifice in an imaginary thin plate that will pass this quantity of air under this pressure.

QUES. 1237.—A fan 20 feet in diameter, running at a speed of 40 revolutions per minute, produces 50,000 cubic feet of air with

a $1\frac{1}{2}$-inch water gauge. What will be the quantity of air passing, and water gauge, if the number of revolutions is increased to 60? What is the equivalent orifice under the first conditions?

I.—Pa. (A)

Ans.—The usual method of solution is to make the quantity ratio equal to the speed ratio of the fan, and the water-gauge ratio equal to the square of the speed ratio. In practice, the quantity and water gauge are both less than these theoretical amounts, the fifth power of the quantity ratio being equal to the fourth power of the speed ratio, and the fifth power of the water-gauge ratio being equal to the eighth power of the speed ratio, then

$$\left(\frac{q}{50{,}000}\right)^5 = \left(\frac{60}{40}\right)^4 = 1.5^4;\text{ and } q = 50{,}000\sqrt[5]{1.5^4} = 69{,}158 \text{ cu. ft. per min.};$$

and
$$\left(\frac{i}{1.5}\right)^5 = \left(\frac{60}{40}\right)^8 \text{ and } i = 1.5\sqrt[5]{1.5^8} = 2.87 \text{ in.}$$

The equivalent orifice of this mine is calculated by the formula

$$A = \frac{.00038\,q}{\sqrt{i}} = \frac{.00038 \times 50{,}000}{\sqrt{1.5}} = 15.51 \text{ sq. ft.}$$

Ques. 1238.—With a fan 8 feet in diameter, making 250 revolutions and passing 62,000 cubic feet of air per minute, when the water gauge stands at 1 inch, what is the equivalent orifice?

I.—Ia.

Ans.—The equivalent orifice of this circulation is calculated as follows:

$$A = \frac{.00038 \times 62{,}000}{\sqrt{i}} = 23.56 \text{ sq. ft.}$$

VARIATIONS IN OPERATION OF A FAN

Ques. 1239.—In a mine where the two openings have a difference of elevation on the surface equal to 200 feet, will the ventilation be the same summer and winter if ventilated by a fan? Why?

F.—Pa. (A)

Ans.—In this case, there will be a difference in the amount of ventilation in summer and in winter. The reason for this is as follows: Assuming that the intake opening of the mine is that having the lower elevation, the natural column due to the difference in outside and inside temperatures will be generally positive in winter and negative in summer, since in winter the temperature of the upcast will be generally greater than the temperature of the 200 ft. of outside air column, and in summer these conditions are reversed.

QUES. 1240.—In a gaseous mine, under the conditions named in the preceding question, at which opening should the fan be located to secure the highest degree of safety, the higher or lower opening? Give reason why. *F.—Pa.* (*A*)

ANS.—The location of the fan at a gaseous mine is usually determined by conditions making it advisable to make the haulage roads the intake airways of the mine; and to avoid the obstruction of these roads by doors, an exhaust fan is employed at the upcast, the downcast being made the hoisting shaft. Assuming that either of the openings is available for hoisting and taking all things into consideration, the lower opening will be preferable for the hoisting shaft, an exhaust fan being placed at the higher opening, set back from the mouth of the shaft, and protected by explosion doors placed in the air conduit over the shaft. By this arrangement, the ventilation will be ascensional and the work of the fan will be assisted by the natural air column during the most important season of the year, the winter season. The hoist will be 200 ft. less than if performed in the deeper shaft. On the other hand, if these conditions are reversed and the fan located at the lower opening, while the other opening is made the hoisting shaft and intake or downcast, not only will the depth of hoist be greater, but there will also be greater danger of the current reversing in case of an explosion or mine fire, on account of the greater depth of the downcast shaft. Also, during the winter season when the temperature of the mine is above that of the outside air, the fan will have a greater work to perform than in the first arrangement mentioned, since the natural air column will be negative acting to retard the circulation.

QUES. 1241.—If the speed of a fan engine should suddenly drop from 70 to 60 revolutions per minute, the power exerted by the engine being the same, what is the probable cause of the variation in speed? Will there be any danger caused thereby? If so, how can it be guarded against? *I.—Pa.* (*B*)

ANS.—There are numerous causes that influence the speed of the fan when the steam pressure remains unchanged, but none of these causes is ordinarily sufficient to reduce the speed of the fan as much as stated in the question. For example, if the main doors separating the intake and return airways at the foot of the downcast are set open, and the air-current short-circuits, returning directly to the upcast shaft, the effect will be to cause a larger quantity of air to pass through the fan, on account of cutting off the resistance of the mine. This increase of circulation through the fan results in a very large increase of resistance in the fan, which reduces its speed, say from 70 to 65 rev. per min. Fans under these circumstances may reduce their speed from 60 to 55 rev. per min., incidentally reducing the power of the engine, while had the power of the engine been maintained by increasing the cylinder pressure, the speed of the fan might have been reduced to only, say, 56 rev. per min. A fall of barometer or a rise of

temperature will result in an increase of the speed of the fan for the same power applied, while the reverse of these conditions will decrease the speed of the fan. One inch of barometer or 10° of temperature ordinarily effects about 1 to 1½ per cent. of change in the speed of the fan. None of these causes are sudden or dangerous in their results, except the setting open of the main doors controlling the circulation in the mine, and this should be guarded against by strict regulations.

QUES. 1242.—On going to the mine Tuesday morning you find that the fan is making 80 revolutions per minute, the steam gauge showing a pressure of 75 pounds, and a current of 45,000 cubic feet of air per minute is passing down the downcast shaft, the water gauge showing a reading of .4 inch. On Wednesday morning you go to the mine and find that the steam gauge shows a reading of 80 pounds, the water gauge .5 inch; and on measuring the air at the downcast shaft you find only 40,000 cubic feet; what would you think was wrong? *E.—Ill.*

ANS.—The decrease in the quantity of air in circulation and increase in the water gauge can only be due to some cause that has increased the mine resistance. A fall has probably occurred on some main airway or return, inside of the point where the water-gauge reading is observed. The increase of the steam-gauge pressure indicates that the fan is doing more work though circulating less air; this is also shown by multiplying the quantity of air in circulation by the water gauge in each case; thus (Tuesday) $45\times.4 = 18$; (Wednesday) $40\times.5 = 20$, the increase of work being in the ratio of 18 : 20, or 9 : 10. Had the power on the air remained constant, the decrease of quantity would have been in the ratio 4 : 5, since for a constant power the quantity varies inversely as the water gauge. This would have reduced the circulation to

$$45{,}000\times\frac{4}{5} = 36{,}000 \text{ cu. ft. per min.};$$

but the increase of the steam gauge has increased this quantity to 40,000, or in the ratio 9 : 10.

QUES. 1243.—What measures would you take to secure the best possible results from a fan the capacity of which is limited and the demands on which approach dangerously close to that limit? *M.—Ill.*

ANS.—To secure the best results with such a fan, wherever possible, enlarge the sectional area of the airways, clean up all falls, enlarge break-throughs, and reduce the distance the air must travel to the lowest possible limit. Divide the air-current into separate splits wherever this is practicable. It may be possible to alter the fan housing so as to give better results.

ACCIDENTS TO FANS

QUES. 1244.—If it becomes necessary to stop a fan for repairs, how will you keep the mine clear of gas in the meantime? What precaution should be taken before stopping the fan?

F.—Pa. (A)

ANS.—Before stopping the fan, it is the duty of the mine foreman to notify all the men in the mine, and to withdraw them, if necessary, from the mine. The withdrawal of the men is made compulsory by the Bituminous Mine Law of Pennsylvania, in case of any accident to the ventilating machinery or interruption of the air-current. To provide temporary ventilation, a steam jet or blower may be arranged at the bottom of the upcast, or in the absence of firedamp in explosive quantities, a small furnace or a fire-basket may be used. Sometimes a fall of water in the downcast shaft will help to maintain the circulation and keep the mine free from gas.

QUES. 1245.—If you have charge of a shaft mine ventilated by a fan, in case of an accident to it, what means would you adopt to insure temporary ventilation? *F.—Pa. (B)*

ANS.—To provide temporary ventilation, a steam jet or blower may be arranged at the foot of the upcast shaft; or, if the conditions are favorable, a small furnace or fire-basket may be used, or a fall of water can sometimes be arranged in the downcast shaft. The erection of a sail or large canvas over the mouth of the downcast shaft, may at times greatly improve the circulation by deflecting the surface winds into the mine.

QUES. 1246.—If you had charge of a mine and the fan engine suddenly broke down, what would you expect to be the condition of the ventilation, and how would you continue to run the mine the rest of the day? *F.—Pa. (B)*

ANS.—The conditions of the mine with respect to ventilation in this case would depend on the amount of ventilation that was produced in the mine by natural causes or by other artificial means. If the fan mentioned was the only means of ventilation, and the natural motive column existing in the shaft or in the slope was very small and of no practical effect, the breaking down of the fan would result shortly in a complete stoppage of ventilation in the mine. Under these conditions whether the mine were gaseous or not the stoppage of the fan should be quickly followed by the men quitting their work, as the Bituminous Mine Law makes it the duty of the mine foreman to order the men to immediately withdraw from the mine.

LEGAL REQUIREMENTS IN REGARD TO FANS

QUES. 1247.—What does the law require in regulating the running of fans? *F.—Pa.* (*B*)

ANS.—In the bituminous mines of Pennsylvania, all ventilating fans must be run continuously day and night, except by written permission of the inspector, or when operations are indefinitely suspended. In all cases, there shall be posted in a conspicuous place at the entrance of the mine a notice in the various languages used by persons employed in the mine, stating the hours the fan will be stopped. The fan must be started at least 2 hours before work is commenced, provided that in case of accident or needed repairs the mine foreman having first provided for the safety of the persons in the mine may order the fan to be stopped to make the necessary repairs. No principal ventilating fan may be placed inside of any dusty mine generating explosive gas. The fan shall be kept running at the speed directed by the mine foreman, but when necessary to prevent its destruction the fan engineer may stop it, and at once notify the mine foreman and give warning to persons in the mine. All fans shall be provided with recording instruments indicating the speed of the fan and ventilating pressure produced, such record for each day to be kept in the mine office.

QUES. 1248.—What does the law require in regulating the relighting of a mine furnace? *F.—Pa.* (*B*)

ANS.—The Bituminous Mine Law of Pennsylvania requires that in mines generating firedamp, if a furnace fire has been extinguished it shall not be relighted except in the presence and under the instructions of the mine foreman or his assistant.

COMPARISON OF FAN AND FURNACE

QUES. 1249.—Plainly state what is the difference between the action of the furnace and the action of the fan. *F.—Pa.* (*A*)

ANS.—The action of a mine furnace used for the purposes of ventilation, is to heat that portion of the air column within the upcast shaft, and thus render the air lighter, bulk for bulk, than the air in the downcast shaft. This causes a difference of pressure between the two shafts, which is at once manifested by causing a current of air to flow from the foot of the downcast to the foot of the upcast. In other words, the furnace by its action decreases the weight of the upcast column in the shaft.

The action of the fan, on the other hand, is to create a difference of pressure between its intake and discharge orifices. This difference of pressure is caused by the centrifugal action of the fan. The pressure at the discharge of a blower fan is always greater than the pressure at the

intake. If the fan is discharging into the atmosphere, the discharge pressure is evidently at least equal to that of the atmosphere, while the intake pressure is below the atmospheric pressure. This causes the atmospheric air to enter the fan at the center, while it is thrown out or discharged at the circumference. The amount by which the atmospheric pressure is reduced at the central or intake orifice of the fan is spoken of as the depression due to the action of the fan. Now, if the intake orifice of the fan is placed in connection with the mine airways, the depression due to the fan will be effective in the airway, and will cause the air from the airway to flow into the fan and be discharged into the atmosphere. On the other hand, if the discharge orifice of the fan is connected with the mine airways, atmospheric air will enter the fan at the center and be discharged at the circumference, into the mine airways, under a pressure due to the fan's action.

The furnace changes the density of the air in the upcast column, and thus creates a ventilating pressure; while, in the case of the fan, the pressure is created by the mechanical action of the fan. In furnace ventilation, the mine is always ventilated under a pressure less than that of the atmosphere; while in fan ventilation, the ventilating pressure may be either below or above that of the atmosphere, according as the fan is exhausting or blowing.

Ques. 1250.—What is the essential difference between the action of the furnace and the action of the fan in mine ventilation? *I.—Ia.*

Ans.—The furnace heats the air of the upcast shaft and thus decreases the weight of the upcast column, thereby destroying the equilibrium between the two shaft columns and creating a ventilating pressure that produces a current through the mine passages from the downcast to the upcast. The exhaust fan produces the same ventilating pressure by reducing the atmospheric pressure at the top of the upcast shaft, by means of its centrifugal action, thereby destroying the equilibrium between the atmospheric columns pressing upon the upcast and the downcast shafts, producing the result just stated. The blower fan produces the same ventilating pressure by adding the pressure due to its centrifugal action to the atmospheric pressure at the top of the downcast shaft. In each case, the ventilating pressure is that due to the centrifugal action of the fan, which produces an air-current in the mine workings.

Ques. 1251.—In what respects is the fan a better means of ventilation than the furnace? *F.—Pa. (A)*

Ans.—Less fuel is consumed in its operation. It requires less attention. The ventilation of the mine is under better control. The amount of air supplied to the mine may be increased or decreased more readily than in the case of the furnace. In case of an explosion in the mine, the fan being upon the surface is more accessible for repairs and attention and the circulation in the airways and the workings of the mine is more readily and quickly increased than in the use of a furnace.

QUES. 1252.—Do the furnace and fan produce ventilation as well in shallow mines as in deep ones? Why? *F.—Pa. (A)*

ANS.—Furnace ventilation is more effective in deep shafts, and fan ventilation in shallow ones. The reason for this is that the power of the furnace depends on the depth of the shaft as well as on the difference in temperature of the outside and inside air, but the power of the fan is practically independent of these factors, being determined principally by its form, size, and speed of rotation. In deep mines, the mine resistance is increased by the shaft resistance; but since the depth of the shaft increases the power of the furnace much more rapidly than it increases the mine resistance, it follows that the furnace is more effective in deep shafts; the fan is more effective in shallow shafts, owing to the lesser mine resistance.

QUES. 1253.—Would you recommend a fan or furnace for a new shaft mine 500 feet deep? Give reasons for your recommendation. *F.—Pa. (B)*

ANS.—I would recommend a fan not only because at that depth the ventilation of the mine may be done cheaper than with a furnace, but because the ventilation of a gaseous mine can be done more safely with a fan than with a furnace. Further, if to the cost of constructing and maintaining a properly isolated furnace is added the cost of lining the lower portion of a furnace shaft with firebrick and maintaining it in good order, it will generally be found that this is much greater than the cost of the construction and maintenance of a good ventilating fan.

QUES. 1254.—A furnace is capable of producing 42,670 cubic feet of air when operated alone, but when combined with a fan, the two produce 46,706 cubic feet per minute; what will the fan produce by itself? *I.—Ia.*

ANS.—Since the furnace and the fan will each perform the same amount of work whether running together or singly; and since the work is always proportional to the cube of the quantity in any given airway,

$$q_1 = \sqrt[3]{Q^3 - q_2^3} = \sqrt[3]{46{,}706^3 - 42{,}670^3} = 28{,}923 \text{ cu. ft. per min.}$$

QUES. 1255.—Which is the more economical method of ventilating the following mine, a furnace or a fan? The quantity of air required per minute is 100,000 cubic feet; depth of shaft, 800 feet; water gauge, 2 inches; temperature of outside air, 62° F.; the fan engine is supposed to consume 5 pounds of coal per horsepower per hour; the specific heat of air is .2374; and the units of heat per pound of coal are taken as 12,000. *I.—Ill.*

ANS.—The required ventilation can, in this case, be produced more economically by means of a fan than by a furnace, as shown by the following

calculation. Assuming a barometer of 30 in., the temperature of the outside air being 62° F., the weight of 1 cu. ft. of this air is

$$w = \frac{1.3273 \times B}{460 + t} = \frac{1.3273 \times 30}{460 + 62} = .076 \text{ lb.}$$

The motive column of this air that will produce a ventilating pressure corresponding to a water gauge of 2 in. is

$$M = \frac{p}{w} = \frac{2 \times 5.2}{.076} = 136.8 \text{ ft.}$$

Another expression for motive column in terms of the downcast air is

$$M = D\frac{T - t}{460 + T}$$

Solving with respect to T, the average temperature of the upcast shaft, and substituting the given values in this formula,

$$T = \frac{460\,M + D\,t}{D - M} = \frac{460 \times 136.8 + 800 \times 62}{800 - 136.8} = 169.6^\circ + \text{ say } 170^\circ \text{ F.}$$

From this average temperature, it is necessary to find the temperature at the bottom of the furnace shaft in order to determine the rise in the temperature of the upcast current produced by the furnace.

The temperature of the air columns at the bottom of the upcast will of course be higher than the average temperature of the upcast, but there are no data available by means of which this temperature can be accurately determined. The difference between the outside temperature and the average temperature of the upcast may be assumed for the increase in temperature of the upcast air, although less than the actual increase; the rise in temperature of the upcast current due to the furnace is, therefore, $170 - 62 = 108°$ F. The amount of coal per hour required to raise the temperature of the air $t°$ F. is given by the formula

$$c = \frac{60\,t\,(Q\,w\,o)}{12{,}000},$$

in which c = weight of coal, in pounds;
t = rise in temperature of the air-current, in degrees Fahrenheit;
Q = quantity of air in circulation, in cubic feet per minute;
w = weight of air before reaching furnace, in pounds per cubic foot;
o = specific heat of air-current, in British thermal units.

Substituting in this formula the given values,

$$\text{Coal} = \frac{60 \times 108\ (100{,}000 \times .0763 \times .2374)}{12{,}000} = 978 + \text{ lb.}$$

For the horsepower of the current,

$$H = \frac{100{,}000 \times 2 \times 5.2}{33{,}000} = 31.52 \text{ H. P.}$$

The coal burned per horsepower per hour on the furnace grate is, therefore,

$$978 \div 31.52 = 31 + \text{ lb.}$$

as against 5 lb. per H. P. per hr. consumed in producing the same circulation by means of a fan.

CHAPTER XIV

PRACTICAL POINTS IN MINE VENTILATION

NECESSITY FOR VENTILATING A MINE

QUES. 1300.—Why is the ventilation of a mine necessary? Describe fully. *F_1.—Ala.*

ANS.—Ventilation is necessary in mine workings in order to supply fresh air to the working face, or to replace the oxygen destroyed by the various forms of slow and rapid combustion that are continually going on, caused by the breathing of men and animals, burning of lamps, oxidation of coal, etc.; and to dilute, render harmless, and sweep away the noxious gases formed by such combustion, as well as those gases transpiring from the coal and contiguous strata.

ESSENTIALS OF A GOOD SYSTEM OF VENTILATION

QUES. 1301.—Specify the conditions that must be fulfilled in order to secure good ventilation in a mine employing a large number of men. *M.—Ill.*

ANS.—Good ventilation in any mine means that a sufficient amount of fresh air be conducted to and circulated along the working face. The essential point is to see that the velocity of this current at the face is sufficient to remove the smoke and gases that accumulate there. This velocity should not fall below 4 or 5 ft. a sec. in a non-gaseous mine, and it may be necessary to increase this velocity to 8 or 10 ft. a sec. in some cases. In a gaseous seam where the gas is issuing freely from the coal, it may be necessary to increase the velocity of the air at the working face to say 450 ft. per min., which is the maximum limit prescribed by the Anthracite Mine Law of Pennsylvania. In the working of thick seams, this velocity at the face may often necessitate a large amount of air passing in the airways. The completing and maintenance of good stoppings is a very important point in the ventilation of a mine. Where the stoppings leak, it is impossible to conduct the whole of the air to the working face. Under such circumstances, there is

often a sufficient amount of air taken into the mine, but the amount passing the working face falls far short of that required. Another important point in good ventilation is to split the air into several currents, thus dividing the mine into two or more districts, each of which has its own ventilation. This method is not only much more economical, but provides fresher air at the working face and greatly lessens the danger of explosions in gaseous mines If an explosion should occur in one district, it is not, as a rule, communicated to the workings in another district.

QUES. 1302.—What is the principal object of ventilation in coal mines? Should there be as much air per man in a non-gaseous mine as is generally required in a gaseous mine? *F.—Pa. (A)*

ANS.—The principal object of ventilation in coal mines is given in the Anthracite Mine Law of Pennsylvania, "to dilute, render harmless, and sweep away smoke and noxious or dangerous gases to such an extent that all working places and traveling roads shall be in a safe and fit state to work and travel therein."

The amount of air required per man per minute in a non-gaseous mine is not as great as that necessary in a gaseous mine, as there is less noxious gas to be diluted and swept away.

QUES. 1303.—Name three essential elements to the efficient ventilation of a mine. *F.—Pa. (A)*

ANS.—Three elements or factors essential to the efficient ventilation of a mine are as follows: The volume of the air-current should be sufficient in the intake airway to meet the requirements of the mine law. The air-current must be conducted properly to the face of the workings, where it is needed, by air-tight stoppings at all break-throughs, and by doors, air bridges, brattices, etc., which should be as nearly air-tight as possible. The velocity of the air-current at the face must not exceed 450 ft. per min. that there may be no danger of the flame of a safety lamp being blown through the gauze of the lamp while the men are working, and when they have not time to constantly observe it; on the other hand, the velocity of the air-current should not fall too low, or it will not be sufficient to sweep out the gases that accumulate in the cavities of the roof, the gobs, and working places.

RELATION OF WATER GAUGE TO EXTENT OF WORKINGS

QUES. 1304.—Does a high water gauge always indicate a large quantity of air passing? What does a low water gauge with a large quantity of air passing indicate? *I.—Ia.*

ANS.—No; a high water gauge always indicates a great mine resistance, or a contracted sectional area, but the great mine resistance may result in a low velocity when the rubbing surface is correspondingly large.

A low water gauge with a large quantity of air in circulation indicates a low resistance and free, unobstructed, or short airways having a good sectional area; this result may be accomplished by splitting the air-current.

QUES. 1305.—If in extending the workings of a mine where the airways are kept of uniform size and condition, the water gauge shows an increased pressure, what, in your opinion, is its cause? *I.—Ia.*

ANS.—It would be natural to expect an increase of pressure due to the increased length of airway, or an increase of rubbing surface. Also, in the extension of the mine workings, there will probably be more air required, and this will also call for an increase of pressure, unless the air-current is split into two or more currents.

QUES. 1306.—State why, in your opinion, the pressure or water gauge increases as the workings are extended, other conditions remaining the same. *F.—Pa. (A)*

ANS.—The ventilating pressure is caused by the resistance that the mine offers to the passage of the air-current. If it were not for this resistance, there would be no pressure or water gauge, and, other things being equal, the pressure or water gauge and the mine resistance increase with the extent of the workings or with the amount of rubbing surface.

QUES. 1307.—Does a large volume of air always require a high water gauge for its circulation in a mine? Why? *F.—Ia.*

ANS.—No; the same water gauge will pass a larger or a smaller volume of air, according as the resistance offered by the mine airways is less or greater.

The water-gauge reading, or pressure per square foot, varies directly as the amount of rubbing surface and inversely as the cube of the sectional area of the airway, for the same quantity of air in circulation.

QUES. 1308.—How can you tell whether or not any obstruction is in an air-course that you have not passed through? *E.—Ill.*

ANS.—If, while the general ventilation of the mine in other districts remains normal, the velocity of the current in a particular air-course is reduced or the movement of the air ceases altogether, then without passing through the airway it is evident that there is an obstruction either in the immediate air-course or its return, caused by a fall of roof or coal, or a door has been set open, allowing the air to short-circuit.

QUANTITY AND VELOCITY OF AIR

QUES. 1309.—What are the principal factors in mine ventilation that determine the increase or decrease of the volume of air passing through a mine? *F.—Pa. (B)*

ANS.—The formula for power is

$$u = \frac{k s q^3}{a^2};$$

by transposing this formula.

$$q = \left(\sqrt[3]{u}\right)\left(\frac{a}{\sqrt[3]{k s}}\right)$$

The volume of air in circulation in any airway is thus seen to be dependent on two main factors: the power and efficiency of the ventilating motor, whether fan, furnace, or natural air column; and the relation between the area a and the friction expressed by $\sqrt{k s}$.

QUES. 1310.—In order to secure thorough ventilation in a mine, about what velocity should the current have at the face of the workings, both in gaseous and non-gaseous mines? *F.—Pa. (A)*

ANS.—The average velocity of the air-current at the face of the workings, in order to secure efficient ventilation, should be from 5 to 6 ft. per sec. It may fall below this, or it may be necessary that it should be greater than this, according to the conditions at the working face. In non-gaseous mines, it is seldom necessary to have a velocity greater than 6 ft. per sec. in a breast; indeed, it is often uncomfortable to work where there is a stronger current. In a gaseous mine, the velocity of the air-current should seldom fall below 6 ft., and it must not exceed 7½ ft. per sec., to come under the requirements of the Anthracite Mine Law of Pennsylvania.

QUES. 1311.—Is it proof of good ventilation, in a gaseous mine, when a very rapid current of air is passing through a small airway? Give reasons. *B.—Pa. (B)*

ANS.—A high velocity, in a small airway, in any mine, is not proof of good ventilation, as a high resistance is developed in the airway, and a large amount of power consumed. A large area and low velocity will accomplish the same result, at a less expenditure of power. For the proof of good and sufficient ventilation in a gaseous mine, the face of the workings must be examined to ascertain that a sufficient quantity of pure air is sweeping the entire face, and that no accumulations of gas are to be found in the cavities of the roof or in waste places. The return current must also be examined carefully to insure that the supply of air is sufficient for the proper dilution of the gases liberated in the workings.

QUES. 1312.—When do you consider the quantity of air entering the downcast shaft sufficient for the ventilation of the workings? *I.—Ia.*

Ans.—The quantity of air entering the downcast shaft must in any case be sufficient to comply with the mining law of the state, in that respect. In the ventilation of thick seams, it will sometimes happen that the quantity of air required by law will not be sufficient to produce efficient ventilation in the mine workings; this is due to the large sectional area of the airways and passages, and the resulting low velocity of the current. The velocity of the air-current at the face should not fall below, say, 3 or 4 ft. per sec., and the quantity of air entering the downcast shaft should always be sufficient to produce this result. In gaseous mines, the quantity of air in circulation should be sufficient to dilute, render harmless, and sweep away the noxious and dangerous gases accumulating in the workings.

Ques. 1313.—In a certain mine, a large volume of air is passing into the downcast and is equally divided among the various splits and returned to the upcast. The stoppings are carefully closed, and cross-cuts are made as the law requires, not more than 60 feet apart. The airways are very large and are kept up and in good condition. The volume of air is nearly three times the quantity required by law, and yet complaints are made of the ventilation, and it is a long time after a shot is fired before the smoke gets cleared out. What do you think is the matter? *M.—Ill.*

Ans.—There should be no trouble on the entries of the mine under these conditions. The air may not, however, be properly deflected into the rooms or chambers and made to sweep the working faces as it should. It may be necessary to put up curtains on the airways to deflect the air into the rooms. Again, the sectional area of the airways, which are very large, may be such that the velocity of the air is too small to remove the gases and smoke rapidly when a shot is fired, although a large quantity of air may be passing; this is often the case in thick seams, where the airways are very large.

Ques. 1314.—In a mine employing 250 persons, each person being allowed 200 cubic feet of air per minute, give the total volume of air required in a day of 10 hours, in cubic feet and its weight in tons, the temperature being 62° F., and the barometer 30 inches. *F.—Pa. (B)*

Ans.—The number of cubic feet of air circulating through the mine in the given time should be

$$250 \times 200 \times 60 \times 10 = 30{,}000{,}000 \text{ cu. ft.}$$

The weight of 1 cu. ft. of air at the temperature and pressure given is

$$\frac{1.3273 \times 30}{460 + 62} = .07624 \text{ lb.}$$

The weight of air that should circulate through the mine in 10 hr. is, therefore,

$$\frac{.07624 \times 30{,}000{,}000}{2{,}000} = 1{,}143.6 \text{ T.}$$

QUES. 1315.—What is the smallest quantity of air required to be circulated per minute to make safe a section of a mine, under the following conditions: In the section, there are two entries and fifty-five rooms. The entries are 9 feet, and the rooms 22 feet wide; the height of the coal is 6 feet, and the working face is known to give off CH_4 gas at the rate of 6 cubic feet of gas per square foot of coal face per hour? *I.—Ill.*

ANS.—The area of fresh working face is always somewhat greater than the area of cross-section of the entries and rooms. The area of cross-section of the two entries is $2(9\times 6) = 108$ sq. ft. If the entries advance at the rate of 4 ft. per day, it is fair to assume that the transpiration of gas will be equally strong over twice this area, or 216 sq. ft. The area of cross-section for fifty-five rooms is $55(6\times 22) = 7,260$ sq. ft. It is safe here also to assume that transpiration takes place over, say, 8,000 sq. ft. of surface. The total area of surface from which transpiration of gas is taking place is then $8,000+216 = 8,216$ sq. ft. The quantity of gas produced in this section of the mine is therefore

$$\frac{8,216\times 6}{60} = 821.6, \text{ say } 825 \text{ cu. ft. per min.}$$

Assuming that the return air-current should not contain more than a maximum of $2\frac{1}{2}$ per cent. of gas, the total air-current in the return, under these conditions, $825\div .025 = 33,000$ cu. ft. per min. The quantity of air passing in the intake of this section of the mine should, therefore, be not less than $33,000-825 = 32,175$ cu. ft. per min. If the mine is dusty, it would be advisable to reduce the percentage of gas allowed in the return current to a maximum of 1 per cent., and the total amount of air to be supplied under these conditions would be

$$\frac{825}{.01}-825 = 81,675 \text{ cu. ft. per min.}$$

QUES. 1316.—State why air-courses should have large areas. Under ordinary conditions, as regards gas, what quantity of air should be circulated in a mine with 200 men and 20 mules? What should be the least dimensions of an airway for that quantity? *F_1.—Ala.*

ANS.—As a general proposition, air-courses should always have as large an area as possible, so as to reduce the rubbing surface per square foot of section. It is not often that an airway is driven having too large an area.

A mine with 200 men and 20 mules should have a volume of air equal to 100 cu. ft. per man and 500 cu. ft. per mule, or,

$$200\times 100+20\times 500 = 30,000 \text{ cu. ft. per min.;}$$

and if this is well distributed, it will easily keep the mine free from gas.

In many cases, the nature of the seam, roof, and bottom practically determines the sectional area of the airways. Generally speaking, for the given volume of air, the area of the air-course should not be less than 50 sq. ft., making the velocity of the air 600 ft. per min.

QUANTITY OF AIR REQUIRED BY LAW

QUES. 1317.—How much air per man does the Pennsylvania Anthracite Mine Law require; and what is the highest velocity of the current permitted by the same law in gaseous mines, and why? *F.—Pa.* (*A*)

ANS.—The Anthracite Mine Law of Pennsylvania specifies as a minimum amount of air per man, 200 cu. ft. per min., and a maximum velocity of 450 ft. per min. The object of this provision is to supply a sufficient amount of air to dilute, render harmless, and sweep away the gases accumulating in the workings. It is not that each man requires 200 cu. ft. per min., but that this amount is the amount deemed necessary to make the mine workings safe from the accumulations of gas. The maximum velocity of the air-current at the face is placed at 450 ft. per min. so that the flame of the safety lamps will not be blown through the gauze, as would often be the case with a higher velocity of the air-current.

QUES. 1318.—What quantity of air will be necessary to ventilate a mine in which 300 men are employed? *F.—Pa.* (*A*)

ANS.—The minimum quantity provided by the Anthracite Mine Law of Pennsylvania is 200 cu. ft. per man per minute, and therefore the minimum quantity will be, in this case, $300 \times 200 = 60{,}000$ cu. ft. per min. It is possible that a greater quantity than this might under some conditions be required, but that would have to be determined by judgment in the mine where the increased quantity was required.

QUES. 1319.—In a mine where 480 men are employed and 53 mules, what would be the minimum quantity of air required? *F.—Pa.* (*A*)

ANS.—The Anthracite Mine Law of Pennsylvania requires the circulation of a minimum quantity of air not less than 200 cu. ft. per min. for each person employed in the mine. In this case, allowing 500 cu. ft. per min. for each mule, and 200 cu ft. per min. for each man, the total quantity of air in circulation should be

$$480 \times 200 + 53 \times 500 = 122{,}500 \text{ cu. ft. per min.}$$

QUES. 1320.—What would be the minimum quantity of air, in cubic feet, circulating per minute permitted under the Anthracite Mine Law, in a colliery employing 500 men, 45 mules, and consuming 50 kegs of powder a day? *I.—Pa.* (*A*)

ANS.—The Anthracite Mine Law of Pennsylvania provides that "The minimum quantity of air produced shall not be less than 200 cu. ft. per min. for each and every person employed in any mine and as much more as the circumstances may require." With the provision in Section 4 of

the same article, "The ventilating current shall be conducted and circulated to and along the face of each and every working place throughout the entire mine, in sufficient quantities to dilute, render harmless, and sweep away smoke and noxious and dangerous gases, to such an extent that all working places and traveling roads shall be in a safe and fit state to work and travel therein," it is evident that some provision must be made to "sweep away smoke." There are cases in which the minimum of the law must exceed 200 cu. ft. per person employed. In thick seams, an allowance of 200 cu. ft. per man per min., and 500 cu. ft. per mule per min., amounting in this case to

$$500 \times 100 + 45 \times 500 = 72{,}500 \text{ cu. ft. per min.},$$

would not perhaps give a sufficient velocity of the air-current at the working face to effectively clear away the smoke and gases; so that to meet the requirements of the law, this minimum amount allowed by law must be increased in order to comply with the requirements. This must be done according to the judgment of the mine inspector. The amount of gas generated by the explosion of 50 kegs of powder would not produce any appreciable effect upon the air flowing through the airways, as the volume of gas produced by the burning of black powder is slightly over 3 cu. ft. per lb. of powder, when the temperature of the gas has fallen to 60° F. This would give a volume of gas, after cooling, of

$$50 \times 25 \times 3 = 3{,}750 \text{ cu. ft.},$$

which is a small volume in comparison to the volume of air passing in the mine. The difficulty, however, arises from the velocity of the current not being sufficient to sweep away the smoke from the working face and from the cavities in the roof where it lodges, and it will be necessary to increase the ventilation until the velocity of the air at the working face is sufficient to do this.

Ques. 1321.—In a mine where 525 men are employed, how many splits of the air-current will be required according to law? *F.—Pa. (A)*

Ans.—The Anthracite Mine Law of Pennsylvania limits the number of persons that may be employed at one time on a single current or split of air, to 75 men. In a mine employing 525 men, the number of splits required by law will be $525 \div 75 = 7$ splits of air.

Ques. 1322.—What should be the area of an air-course in a split, where the full complement of persons are employed, and where safety lamps are used, to allow the free passage of air, the velocity not to exceed the limit provided for in the Anthracite Mine Law? Give length of collar, spread between legs, and height you would make such an airway in the Mammoth seam. *F.—Pa. (A)*

Ans.—The Anthracite Mine Law of Pennsylvania limits the number of persons employed on a single air-current or split to 75 persons. The law requires a circulation of 200 cu. ft. of air per min. for each person employed

on the current, and limits the velocity of the current to 450 lin. ft. per min. where safety lamps are employed. With a full complement of men, under these conditions, the minimum circulation in this case would be $75 \times 200 = 15{,}000$ cu. ft per min. in the airway. The velocity of the current being 450 ft. per min., the required area of the airway is

$$15{,}000 \div 450 = 33\tfrac{1}{3}, \text{ say } 40 \text{ sq. ft.}$$

To give this area in the clear, allowing the legs to spread 4 in. for each foot of height, and making the clear height under the collar 5 ft., the average width between the legs is $40 \div 5 = 8$ ft. The total spread of the legs is $5 \times 4 = 20$ in. And subtracting one-half of this spread from the average width, the length of collar between the notches is 8 ft. − 10 in. = 7 ft. 2 in. In the Mammoth seam, this airway would probably be driven 8 ft. high and from 10 to 12 ft. wide.

QUES. 1323.—What are the requirements to provide for the ample and efficient ventilation of bituminous mines?

I.—Pa. (B)

ANS.—The Bituminous Mine Law of Pennsylvania requires that at every mine, whether shaft, slope, or drift, there shall be provided and maintained ample means of ventilation for the circulation of air through the main entries, cross-entries, and all other working places, to an extent that will dilute, carry off, and render harmless the noxious or dangerous gases generated in the mine, affording not less than 100 cu. ft. per min. for each and every person employed therein; but in a mine where firedamp has been detected the minimum shall be 150 cu. ft. per min. for each person, and as much more in either case as one or more of the mine inspectors may deem requisite. Section 2 requires that not more than 65 persons shall be permitted to work in the same air-current, provided that a larger number, not exceeding 100 persons, may be allowed by the mine inspector when in his judgment it is impracticable to comply with the foregoing requirement, and mines where more than 10 persons are employed shall be provided with a fan, furnace, or other artificial means to produce the ventilation, and all stoppings between main intake and return airways hereafter built or replaced, shall be substantially built of suitable material which shall be approved by the inspector of the district. Section 3 provides that "all ventilating fans shall be kept in operation continuously night and day, unless operations are indefinitely suspended, except when written permission is given by the mine inspector of the district to stop the same. All ventilating furnaces in mines shall, for 2 hours previous to beginning work, and during working hours, be properly attended by a person employed for that purpose. Doors must be hung so that they will close themselves, or be otherwise provided with springs or pulleys so that they cannot be left standing open, and all principal doors through which cars are hauled shall be provided with an attendant to open and close said door when cars are passing through them, unless an approved self-acting door be used.

QUES. 1324.—In a gaseous mine where 30 persons are employed, would you consider the ventilation sufficient, provided that the

quantity of air in circulation is equal to 150 cubic feet per minute per man? *B.—Pa. (B)*

Ans.—This quantity of air would be considered a sufficient quantity for the ventilation of the mine, if the current is properly conducted around the working face, and if the velocity of the air current at the face is sufficient to dilute, carry off, and render harmless the gases generated.

Ques. 1325.—The outlet of a mine is 8 ft. × 8 ft.; at what velocity must the air travel per second to comply with the Bituminous Mine Law of Pennsylvania? Where would you measure the air-current to satisfy yourself that the mine was being properly ventilated? Assume conditions. *F.—Pa. (B)*

Ans.—In reply to this question, assume that 65 men, the maximum number of persons allowed by law on one air-current, are employed in this split or airway. Assume also that there is no gas being liberated, which makes the amount of air required by law $65 \times 100 = 6{,}500$ cu. ft. per min. The velocity of the air-current in this airway will then be

$$\frac{6{,}500}{8 \times 8 \times 60} = 1.7 \text{ ft. per sec., nearly,}$$

which is a low velocity and might necessitate increasing the quantity of air passing, in order to give proper ventilation.

The velocity of the air-current should be measured at the mouth of the split and at the inside break-through, in order to make certain that the entire quantity of air is passing around the face of the workings.

Ques. 1326.—The velocity of the current in a return airway is 150 feet per minute. The airway is 4½ feet in height by 6 feet in width. The number of men employed in the section ventilated by this current is 80, with 8 mules and their drivers. Is the ventilation sufficient? *E.—Ill.*

Ans.—The Illinois Mine Law specifies that the circulation in a mine must equal 100 cu. ft. of air per min. for each person, and 600 cu. ft. for each animal employed in the mine. Assume a driver for each mule. If then $80 + 8 = 88$ men, and 8 mules are employed, the quantity of air required by law in this section of the mine is $88 \times 100 + 8 \times 600 = 13{,}600$ cu. ft. per min. The area of the airway is $4\frac{1}{2} \times 6 = 27$ sq. ft. The velocity of the air-current in this airway, to supply the required quantity of air, should therefore be $13{,}600 \div 27 = 503.7$, say 500 ft. per min. As the velocity in the airway is stated as only 150 ft. per min., it is not nearly sufficient for the ventilation of the mine as required by law.

Ques. 1327.—We have a mine that is working 312 miners, 49 day men, and 22 mules; how many cubic feet of air per minute would you expect to keep in circulation when 80 per cent. of the miners are at work in the mine? *E.—Ill.*

ANS.—Estimating on the percentage of miners at work, the circulation required by law is

$$.80(312+49) 100+22\times 600 = 42{,}080, \text{ say } 45{,}000 \text{ cu. ft. per min.}$$

QUES. 1328.—What is the Illinois Mine Law in reference to the division of a large mine into sections? *M.—Ill.*

ANS.—The Illinois Mining Law states as follows:

The main current of air shall be so split or subdivided as to give a separate current of reasonably pure air to every 100 men at work, and the inspector shall have authority to order separate currents for smaller groups of men, if, in his judgment, special conditions make it necessary.

QUES. 1329.—Give, in substance, the law of Indiana in regard to: the amount of air to be forced into a mine; how it shall be circulated; what examination shall be made of working places with respect to their ventilation; how the ventilation shall be provided; in regard to splitting the air; in regard to break-throughs; in regard to doors. *F.—Ind.*

ANS.—The quantity of air required by law is 100 cu. ft. per minute for each person and 300 cu. ft. for each animal employed in the mine.

It must be circulated around main entries, cross-entries, and working places so that they shall be free from standing gas of all kinds.

Where firedamp is known or supposed to exist, the working places shall be carefully examined with a safety lamp by a competent fire-boss immediately before each shift.

By any suitable appliance, as furnace, fan, steam jet, or water fall.

The air-current shall be split so as to give a separate current to at least each 50 persons.

Break-throughs must be made in every room at least every 45 ft., and all except the last shall be closed and made air-tight.

Doors for directing the air-currents shall be opened and closed by persons designated for that purpose.

QUES. 1330.—In a given mine, the main north entry runs 700 feet, the first east and the first west each run 200 feet, the second east and the second west each run 125 feet, all being double entries. The main south entry runs 300 feet, with a pair of entries on each side, each 150 feet in length. Allowing 33 feet for each room and pillar, and one man to a working place—entry and rooms: How many men would be employed? How many mules would be needed? What air measurements should be shown at the face of each entry? *F.—Ind.*

Ans.—	Men
Each 200-ft. entry gives six rooms, 6×4	24
Each 125-ft. entry gives three rooms, 3×4	12
Each 150-ft. entry gives four rooms, 4×4	16
16 entries, one man in each	16
Total men at work mining	68
Three drivers, two tracklayers, one timberman, one cager	7
	75

There would be required 3 mules.

Without allowing anything for leakage, there would be required by law for, say, 50 men and 2 mules,

$$50\times100+2\times300 = \text{say } 6{,}000 \text{ cu. ft. per min.}$$

for the circulation on the north side: and for, say, 25 men and 1 mule

$$25\times100+300 = \text{say } 3{,}000 \text{ cu. ft. per min.}$$

on the south side; making 9,000 cu. ft. of air at the inlet of the mine. The total quantity of air going into the mine should be divided at the foot of the downcast, 6,000 cu. ft. going to the north side, which amount should be found at the face of all entries on the north side, and 3,000 going to the south side, this amount being found at the face of all the south side entries.

This answer assumes the entire length of each entry is available for room-turning. In most cases, it is not usual to turn rooms inside of the last break-through, as long as the entry is running.

Ques. 1331.—What are the essential laws pertaining to the ventilation and working of mines in Iowa? *F.—Ia.*

Ans.—The essential laws in reference to the ventilation and working of mines in Iowa may be briefly enumerated as follows: Iowa Code, Sections 2478–2484 inclusive, relate to the qualifications, examination, appointment, compensation, powers, duties, reports, and removal from office of the state mine inspectors. The law also requires that an accurate map shall be kept of each mine, showing the area mined or excavated, and shall be extended or brought up to date on or before the first day of September of each year. The map must be drawn to a scale not less than 100 ft. to the inch, and kept exposed in the office of the mine, subject to public inspection. The law further provides for escape and air shafts, and allows 1 year in which to make such outlets, but restricts the number of men employed during that time to 20 men. The law requires that a circulation shall be maintained in the mine of not less than 100 cu. ft. of air per min. for each person, and 500 cu. ft. for each mule or horse employed. All mines operated by shaft or slope shall be provided with proper speaking tubes or signal apparatus extending from the surface to the shaft or slope bottom. Also, safety catches and covers to cages, safety gates, and brakes to winding drums, and trails or dogs attached to each train upon a slope or incline must be employed. The winding engine must be in charge of a sober and competent engineer, and not more than 10 persons are allowed upon any cage at one time. Boys under 12 years of age are prohibited from working in the mine. Sections 2490

and 2491 provide for the maintaining of suitable scales of standard make at all mines where payment is made upon the basis of the weight of coal mined. The weighman employed must be sworn to keep the scales correctly balanced, and to weigh accurately, and correctly record the weight of each car of coal delivered. The privilege is also secured to the miners of furnishing, at their own expense, a competent check-weighman if they so desire. The law also specifies that where the miner is, by contract, to be paid by the ton or other quantity, unless otherwise agreed upon in writing, the owner or agent shall weigh the coal before screening and the miner shall be credited at the rate of 80 lb. per bu. and 2,000 lb. per T., but no payment shall be demanded for sulphur, rock, slate, blackjack, dirt, or other impurities loaded or found in the coal.

Sections 2493–2495 provide that only pure animal or vegetable oil, paraffin, or electric lights shall be used for illumination purposes in any mine. The standard of purity of oils is by law determined by the State Board of Health, such standard to be recognized by the courts of the state. Any oil used in the mine is subject to the test of the state mine inspector. Penalties are attached for the non-performance of these duties. All mine foremen and hoisting engineers must have a certificate of competency.

QUES. 1332.—What should be the quantity of air for a mine producing 300 tons of coal per day? What should be the effective horsepower of the ventilator required to furnish it, when the water gauge stands at 1 inch? *I.—Ia.*

ANS.—The average output of coal per miner per day in Iowa is, say, 2.5 T., then $300 \div 2.5 = 120$ miners required to produce this quantity of coal per day. To this number must be added, say 120 helpers or loaders, and 10 company hands, including drivers, timbermen, trackmen, trappers, and cagers. There will also be required, say, 5 mules in this mine. The quantity of air required by law for the ventilation of such a mine would be

$$100(120 + 120 + 10) + 500 \times 5 = 27{,}500 \text{ cu. ft.}$$

as a minimum quantity. We should estimate, however, upon a circulation of, say, 30,000 cu. ft. of air per min. The effective horsepower for this circulation is calculated as follows:

$$\frac{30{,}000 \times 1 \times 5.2}{33{,}000} = 4.7 \text{ H. P.}$$

INCREASING THE QUANTITY OF AIR

QUES. 1333.—If, in a deep shaft mine, extensively developed, with the fan producing 100,000 cubic feet of air per minute, 40 per cent. of which you measured near the face of the entries, would you consider the ventilation of the mine good or defective? If defective, what would be the probable cause, and how would you

remedy the same? Answer the same question, assuming the mine to be a drift opening with a very shallow cover.

F.—Pa. (B)

Ans.—Since only 40 per cent. of the air in circulation reaches the face, the ventilation is defective, the probable cause being the leakage of the air through the doors, stoppings, and overcasts.

The remedy is to be found in repairing all stoppings, doors, and overcasts, to prevent the leakage of air, and by avoiding the use of doors by the building of overcasts wherever practicable.

Under a shallow cover, it is possible for the leakage of air to occur through surface breaks, which should be stopped as far as possible, but this may often prove a difficult matter to accomplish.

Ques. 1334.—If you found a deficiency of air in a mine, in what way would you proceed to remedy the same? *F.—Pa. (A)*

Ans.—The circulation of air in a mine, or the quantity of air passing per minute in the main intake airway, may be increased by increasing the ventilating power or by increasing the sectional area of the airways or decreasing the rubbing surface. Start first by cleaning up the airways and any falls of roof and coal that would block the air-current, enlarging the break-throughs and reducing the sharp angles and other projections in the airway that represent an increased rubbing surface; as far as practicable shorten the distance the air must travel, thereby reducing the rubbing surface; and finally, if the quantity of air traveling is still insufficient, divide the air-current into two or more splits, which will have the effect of increasing the area of passage for the mine in the ratio of the number of splits.

Ques. 1335.—If the ventilation of a mine is insufficient where the power is fully utilized, what can you do to increase the amount of air in circulation? *I.—Ia.*

Ans.—If the power is fully utilized in the present ventilation of the mine, the only means by which the quantity of air in circulation can be increased, without additional power, is to clear up the airways, enlarge the break-throughs, and straighten the air-courses as much as possible, thereby reducing the length the air must travel. All old curtains and brattices that are not required should be taken down and the air be made to travel in as direct a course as possible. If this does not produce the desired result, recourse must be had to splitting the air; that is to say, causing it to travel in two or more currents, which has the same effect as increasing the area of the airway. The volume of air passing will be directly proportional to the number of splits made, provided that these are of the same length and the power remains constant. The pressure will be reduced in the same ratio as the quantity is increased under these conditions.

Ques. 1336.—How could you increase the ventilation in a mine without increasing the power? *F.—Pa. (B)*

Ans.—The ventilation in a mine may often be increased without increasing the power, by cleaning up the airways, enlarging the break-throughs, and shortening the distance the air must travel as far as practicable. Where possible, the air should be split into two or more currents, thereby increasing the sectional area of the mine for the same rubbing surface.

Ques. 1337.—In a mine where the main air-course and return are each of the same length, the roof has fallen badly in the former, while the air is foul in all the entries and working places, yet the fan is run to its full capacity. Name three ways by which the amount of air can be increased in such a mine without enlarging the fan. *I.—Ia.*

Ans.—The quantity of air in circulation may be increased by clearing up the falls on the main air-course. The quantity of air in circulation may be increased by increasing the speed of the fan, but this will necessitate a large increase of power. If this is a shallow mine, it may be cheaper to sink an air-shaft at the head of the entries and cause the air to travel in two splits from the downcast to the upcast shaft. It may be possible to build a furnace at the foot of the upcast shaft.

Ques. 1338.—In a coal field 2 miles square, both openings are at the lowest point of the coal property, and the seam rises on a grade of 2½ per cent. for a distance of 6,000 feet. The depth of strata at the openings is 210 feet, and the surface is perfectly horizontal over the whole extent of the property. The ventilation is produced by a forcing fan 15 feet in diameter. It is found to be unable to supply the lawful quantity of air at the face of the workings; therefore, with a view to economy, what means would you adopt to insure the lawful amount of ventilation for the mine? *F.—Pa. (B)*

Ans.—The face of the workings in this seam is $6{,}000 \times .025 = 150$ ft. higher than the foot of the shaft, and the depth of a shaft sunk at the face would therefore be $210 - 150 = 60$ ft. By sinking this shaft at the face, the distance for the air to travel will be reduced one-half. Since the rubbing surface is unchanged and the sectional area doubled, the same ventilating pressure will then circulate $2\sqrt{2} = 2.828$ times the quantity of air as before. If desired, the fan could be moved to the new air-shaft and changed to an exhaust fan.

SLOPE AIRWAYS

Ques. 1339.—In driving a slope 18 feet wide and 6 feet high, in a vein 3 feet thick, how wide would you drive your airways on either side? Give reasons for it. *F_1.—Ala.*

Ans.—Assuming that the main slope, 18 ft. wide, is the intake airway, and that the air returns through the smaller airways on both sides of this slope, the area of these airways should be each somewhat greater than one-half of the area of the main slope or intake, since each of these return airways must accommodate one-half of the return current, the volume of which has probably been increased by the temperature of the mine and the mine gases. The area of the intake airway is $6 \times 18 = 108$ sq. ft., and hence the area of each return airway should somewhat exceed $108 \div 2 = 54$ sq. ft. On account of the thinness of the seam (3 ft.) it may be more practicable to reduce the height of these return airways, driving them 14 ft. wide and only taking down 1 ft. of roof, making them 4 ft. high instead of 6 ft. high, as in the case of the main slope, and giving each an area of $4 \times 14 = 56$ sq. ft. This will save the handling of a large amount of dead material; or by driving the airways 18 ft. wide, 4 ft. of this width may be utilized in which to stow the roof slate.

Ques. 1340.—If you had a slope 16 feet wide and 6 feet high in the clear, how would you drive the airways? State approximately without going into figures. *F_1.—Ala.*

Ans.—If the seam is gaseous, airways should be driven parallel to the slope, one upon each side of the same, leaving pillars varying from 25 to 30 ft. in width between the slope and each airway. If there is no gas present, a single airway will be sufficient. The width of the slope pillars will depend largely on the character of the roof, floor, and coal, and the thickness of the seam and depth of cover.

VENTILATION OF ROOM-AND-PILLAR AND LONGWALL WORKINGS

Ques. 1341.—Which is the easier to ventilate, room-and-pillar or longwall workings? Give the reasons for your answer. *M.—Ill.*

Ans.—Longwall workings are more easily ventilated than room-and-pillar workings, because the air-current is conducted along the working face where it is required. For the same length of working face, the distance traveled by the air is less in longwall work than in room-and-pillar work, and there is less loss of air due to leaky stoppings, doors, curtains, brattices, etc.

AIR-CURRENT AT FACE OF WORKINGS

Ques. 1342.—Is it safe to pass a current of intake air through the abandoned portions of a mine, and then conduct it to the face of the workings; if not, why not? *F.—Pa. (B)*

Ans.—It would not be safe for the intake current to traverse abandoned workings before reaching the working face of a mine, for the reason that the

gases that may be liberated in the abandoned workings would be carried forwards to the working face with dangerous results. These gases are often poisonous or explosive. The abandoned workings should be ventilated by a separate current of air, or by the return current from the mine, which should then be returned directly to the upcast.

QUES. 1343.—Describe what in your judgment you consider the best method of conducting the air-current to and along the faces of all working places. *F.—Pa. (A)*

ANS.—The best method of conducting the air-current to and along the working faces is to make all air-courses as direct and straight as practicable, enlarge break-throughs or cross-cuts to regulation size, clear up all falls, make tight stoppings and doors, and keep all brattices as near the face as possible, and conduct the air-current toward the face on the narrow side of the brattice.

QUES. 1344.—In driving a single place or prospect entry in advance of the workings, how would you conduct the air to the face? *F_2.—Ala.*

ANS.—By carrying an air brattice along one rib of the entry. The air should be carried up the narrow side or behind the brattice, returning by the road as shown in Fig. 1. The width of such a heading, when approaching abandoned workings, as specified in the Alabama Mine Law, should not exceed 8 ft. The law also provides that a bore hole shall be kept at a distance not less than 3 yd. in advance of the heading, and flank holes shall be bored upon each side of the heading 6 ft. apart and 6 ft. in depth. A close watch should be kept for any increase of water or gas at the face, in the underclay or the seam itself, or in the overlying strata. Only safety lamps should be permitted to be used at the face. Plugs should be kept in readiness at the face for instant use, and only careful and experienced men should be employed in the heading.

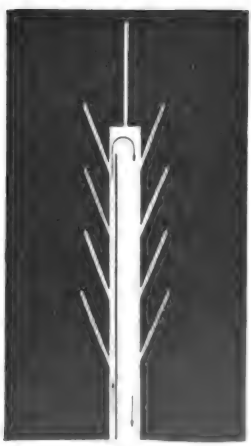


FIG. 1

QUES. 1345.—In a certain mine there is a pair of entries in which all the rooms and entry faces are giving off gas so fast as to make them dangerous. Describe how you would keep the faces clear while driving from one break-through to another. *F.—Ind.*

ANS.—Under these conditions, the face of the entries and of the rooms can only be maintained free from gas and in a safe condition by constructing in each entry and room a temporary brattice extending from the outby rib

of the last break-through or cross-cut forwards along one side of the entry or room, say 2 or 3 ft. distant from the rib of the same, to a point near the working face, as shown in Fig. 2. This temporary brattice is usually constructed by setting posts from 4 to 6 ft. apart, and nailing brattice cloth to these to serve as a partition to conduct the air forwards to the face. As the opening progresses and another break-through is made, the brattice must be taken down and carried forwards, as it is needed; by this means the air-current is obliged to travel around the brattice and sweep the face.

FIG. 2

VENTILATION OF RISE AND DIP WORKINGS

QUES. 1346.—What class of workings is more easily ventilated, rise or dip workings, and why? *F.—Pa. (A)*

ANS.—Workings driven to the rise are generally more difficult to ventilate than those driven to the dip, under similar conditions. The reason for this is that there is always a difference of temperature between the intake and the return currents. The air absorbs heat from the mine to a certain degree; but to a much larger extent it absorbs heat at the face from the men at work there, and from the burning of their lamps. As a result, the return current of any section or air split is almost always lighter than the intake; and where the entries leading to the face rise or fall, there is established an air column. It is evident that this air column will favor the ventilation in entries running to the dip, as the warm air tends to rise from the face toward the main gangway. The reverse of this is likewise evident in rise entries, as the warm air in this case will tend to remain at the face. It will require a greater pressure of the air-current to ventilate rise workings under these conditions. The only exceptions to this general rule occur when the air coming into the mine is cooled as it traverses the airways; this takes place in a few instances in the summer season, when the outside temperature is very much above that of the mine, the intake current may then be warmer, and the return colder. Or when much blackdamp is given off at the face of either rise or dip workings it may make the rise workings easier and the dip workings more difficult to ventilate. These exceptions are, however, so rare as to scarcely need mention.

QUES. 1347.—If you have a pair of entries going to the dip and then rising, in which you have allowed blackdamp to accumulate, what means would you provide for its immediate removal? *I.—Ia.*

Ans.—To remove this damp would require a strong and plentiful air-current. All of the air possible should be thrown into this section.

Ques. 1348.—Suppose that you have three pair of entries, the mouth of each pair of entries being the same distance from the downcast shaft. One pair runs to the dip, one is on the level, and the third is to the rise; which pair will be the most easily ventilated, and why? *F.—Ia.*

Ans.—Assuming that the air of the mine has a higher temperature than the outside air, the temperature of the return current in each of the three pair of entries named will be higher than that of the intake. As a result, if there is no large amount of blackdamp given off at the face, there will be natural air columns formed in both the rise and the dip entries. The air column of the dip entry will assist ventilation, since the lighter return air rises as it travels. The air column of the rise entry will, on the other hand, retard ventilation, because the lighter return air must, in this case, fall as it travels. The natural air column formed in the dip entry, acting to assist ventilation, will render this pair of entries more easily ventilated than either of the others; while the air column formed in the rise entry, acting to retard ventilation, will render the ventilation of that pair of entries the most difficult.

SAFE AND EFFICIENT VENTILATION

Ques. 1349.—Explain the safest and most effective way of circulating air through mines. *F.—Pa. (A)*

Ans.—The safest and most effectual method for the ventilation of mine workings is to divide the main air-current into two or more splits, as near as practicable to the bottom of the downcast, each of these splits being employed for the ventilation of separate districts of the mine. These splits, which are known as primary splits, should be again divided into other secondary splits, at any point of the mine in which such division can be accomplished to advantage. By this means, each district of the mine is provided with its own circulation and receives purer air, inasmuch as the return air from any district in the mine is not conducted around the working face of any other district but passes directly into the main return airway, and thence to the bottom of the upcast shaft. Any derangement of the current in one district does not necessarily affect the circulation in other districts of the mine. If, for any reason, a larger quantity of air than usual is required at any one point in the mine, this can be accomplished readily in this method by reducing the quantity of air in any one or in all of the other splits. This is an unquestioned advantage, especially in the ventilation of gaseous mines, as the ventilation by this means is more readily controlled.

QUES. 1350.—The main air-course in a certain mine is adjacent to some very extensive old workings from which large quantities of blackdamp escape into the airway. Describe, in full, how brattices should be constructed to prevent this. *F.—Ind.*

ANS.—Beginning at the foot of the downcast shaft, or at the mouth of the intake, or the nearest point thereto at which the difficulty occurs, an air-tight brattice should be constructed by setting a line of posts in the airway, say from 12 to 18 in. from the rib adjacent to the old workings. This brattice is closed to the airway throughout its entire length, except for a small leak of air sufficient for the ventilation of the space behind the brattice, and is carried along the rib, at an equal distance from it, as far as is necessary, to control the escaping gas. A connection is then made to allow the gases to pass into the return airway as near the foot of the upcast shaft as possible, by constructing a box or overcast of sufficient size to carry off the gas accumulating from the old workings. By this means, the gas will be conducted immediately into the return current.

QUES. 1351.—What are the duties of mine managers (Illinois) in reference to ventilation? *M.—Ill.*

ANS.—The mine manager must see that cross-cuts are made at proper distances apart to secure the best ventilation at the working face; and that all stoppings are promptly and properly built; he must keep a careful watch over all ventilating apparatus and the air-currents in the mine; in case of accident to the fan or other machinery, and consequent stoppage of the ventilation, he must at once withdraw all the men from the mine and prohibit their return until the proper circulation has been reestablished. He must measure the quantity of air in circulation with an anemometer at least once a week at the inlet and outlet, and keep a record of such measurements for the information of the inspector.

QUES. 1352.—What precautions are necessary in order to maintain a good current of air throughout the entire workings of a mine? *F.—Pa. (B)*

ANS.—It is necessary that all stoppings, doors, overcasts, etc. shall be substantially built and practically air-tight, in order to properly conduct all the air into the workings. Where necessary, brattices should be used to deflect the air-current to the face of headings and rooms; also canvas doors should be placed at the mouths of rooms where necessary, to deflect the air-current through the cut-throughs and along the working face to such chambers. Reliable ventilating machinery should be employed capable of supplying an ample quantity of air for the ventilation of the mine. Duplicate fans and engines are often used to avoid shutting down the mine in case of a breakdown either in the fan or engine. It is important to divide the ventilation of the mine into districts, each district having its own intake and return current connecting with the main intake and return. This will provide a better distribution of the air to each district, and make the ventilation more easily controlled in case of accident.

QUES. 1353.—How would you proceed to reduce the number of doors in a mine, and still maintain a good circulation of the air-currents? What advantages would be gained by so doing? *F.—Pa.* (*A*)

ANS.—The number of doors in a mine may be reduced by splitting the air-current and building overcasts or air bridges at the points where there were formerly doors, and ventilating each pair of entries by a separate split of air, as shown in Fig. 3. The fresh air-current, or the return air, will pass over these overcasts, or bridges, according as the haulage is accomplished upon the return air, or upon the intake air-course. The advantages of so doing are that each section receives its individual air-current and thus each has a separate portion of air. An extreme accumulation of explosive gases in a single return is also avoided. There is also a saving in door tenders and in repairs of doors, and the air-current is not interrupted by the opening of doors.

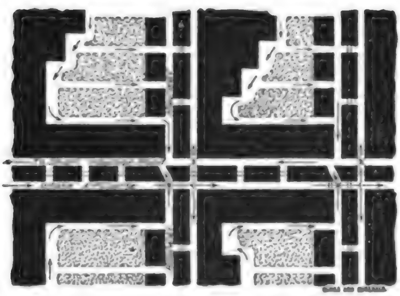


FIG. 3

VENTILATION OF GASEOUS MINES

QUES. 1354.—If you were a mine foreman in a gaseous mine, how would you arrange and distribute the air-currents to insure the greatest safety to life and property? *F.—Pa.* (*B*)

ANS.—The ventilation of the mine should be arranged in separate districts, each district taking its air from the main intake and discharging it into the main return. Overcasts should be used in place of doors wherever practicable, to avoid the danger of the circulation being stopped by the careless setting open of a door. The quantity of air should be distributed according to the need of each district, and the velocity of the air should be sufficient to sweep away the gases accumulating in each district. By this means, the ventilation is more easily controlled to suit the conditions in the several districts of the mine

QUES. 1355.—What system would you adopt in conducting your ventilation through the workings of a gaseous mine to prevent explosions? *B.—Pa.* (*B*)

ANS.—The panel system of ventilation will secure for every district of the mine a separate and distinct circulation that is easily controlled, giving to each district a copious supply of fresh air sufficient to dilute and remove all inflammable gases.

QUES. 1356.—What system would you adopt to keep a constant current of air flowing through the mine so as to prevent an accumulation of gas, and keep the mine in a safe, healthy condition? *F.—Pa. (B)*

ANS.—The circulation in the mine should be independent, as far as possible, of doors and regulators. If the latter are used, they should be provided with a suitable lock to prevent their being tampered with and the circulation deranged. Wherever doors are used, there is the liability that these will be set open at any time and carelessly left in this position, which would result in a serious derangement of the circulation. To avoid the use of doors, overcasts should be built at the mouth of each pair of cross-entries to conduct the return or the intake current, as the case may be, across the other entry or airway. Each pair of cross-entries thus forms a separate district of the mine with respect to ventilation, and a reliable circulation of air is thereby provided. Also, the ventilating apparatus may be in duplicate, giving a reserve fan and engine at a gaseous mine.

QUES. 1357.—How would you lay out your works so as to insure the least damage in case of an explosion? F_1.—*Ala.*

ANS.—To reduce the damage in case of explosion, the mine should be divided into districts, each district having its own circulation of air, so as to keep an explosion confined as much as possible to one portion or district of the mine. The main point, however, is to avoid, as far as possible, the liability to explosion by keeping the mine well ventilated and free of gas.

QUES. 1358.—What method of ventilation lessens the danger of an explosion and reduces friction? State your reasons for the same. *M.—B. C., Canada*

ANS.—The division of the mine into ventilating districts, each district having its own air-current. The gases generated in one portion of the mine are not then carried by the air-current into another portion, but are delivered directly to the main return airway.

If an explosion occurs in one district, the men in the other districts may escape without the danger of suffocation from the afterdamp. For the same quantity of air in circulation, the velocity in the airways is less and the friction thereby reduced. When the power on the air remains unchanged, however, splitting does not reduce the friction. In shallow shafts of such sufficient area that the shaft resistance may be practically ignored, the effective power applied to the airways is not changed by splitting, the rubbing surface also remains unchanged, and the velocity of the air is therefore the same after, as before splitting. A constant rubbing surface and a constant velocity can only produce a constant friction. In order to reduce the friction the power applied to the air-current must be reduced.

QUES. 1359.—Describe what system of ventilation and general management you would adopt in a gaseous mine in order to keep

the mine in a safe condition (both as to explosions and other causes). *B.—Pa.* (*B*)

ANS.—The exhaust system of ventilation should be employed, and haulage should be performed on the main intake airway to avoid the danger of the ignition of gas in the return current. An abundant ventilation should be maintained throughout the mine, and the management should enforce strict regulations relative to the use of locked safety lamps and open lights, the latter being allowed on the main intake only. If blasting is performed, the work should be done by experienced men. Flameless explosives should be used and care should be taken to avoid any accumulation of dust at the working face or in the entries; where the coal is particularly inflammable a system of spraying should be adopted before firing shots. Strict regulations should be enforced relative to the handling of explosives in the mine and the amount of explosive allowed each man. There should be a thorough system of examining the mine and all its working places and passageways before each shift.

QUES. 1360.—In developing a mine and mining a seam of coal generating large quantities of gas, how should the mine be planned? What precautions should be used in the developing and mining so as to comply with the law? *I.—Pa.* (*B*)

ANS.—The opening of a gaseous seam of coal should be planned with respect to furnishing a large quantity of air to the several districts of the mine. The main haulage road should be made the intake of the mine, in order to avoid the risk arising from the use of lamps in the return current, which may at any time become overcharged with gas. The triple-entry system is generally adopted for the main haulage roads of such a mine, the middle entry of the three being made the intake and haulage road, with a main return airway on each side. The cross-entries or gangways are driven double. Locked safety lamps should be used exclusively in the workings, and in all entries or passageways where a sudden inflow of gas is liable to occur by reason of the subsidence of the roof or other cause; and the use of electric wires should be prohibited in such mines or parts of mines, unless said wires and electrical appliances are so constructed and protected as to secure freedom from sparking or flaming, as required by the Bituminous Mine Law of Pennsylvania (Art. 5, Sec. 5). Rule 15 of the General Rules prohibits the firing of shots where locked safety lamps are used, except with the consent of the mine foreman or other duly authorized person.

QUES. 1361.—Describe, in detail, the developments and general arrangements you would expect to find at a large gaseous shaft mine, in full operation, the same being operated on modern scientific principles and according to law. *I.—Pa.* (*B*)

ANS.—The general plan of such a mine should be so arranged as to supply a copious current of fresh air to the several districts into which the mine

should be divided. This general plan should include at least a triple-entry system of main roadways, the central entry being made the intake airway and haulage road, and the two side entries the return airways for each side of the mine, respectively. If the panel system is used, as would be advisable in case the roof or floor is weak or the coal frail, each panel should have its own separate ventilating current. If the conditions of the roof and floor are such as not to require this, the rooms should at least be driven and ventilated in sets according to the amount of gas being given off at the working face. Each set of rooms should have a separate current or split of air taken from the main airway through the innermost room of the set, and conducted back along the working face and returned through the outermost room of each set to the main return current. The most reliable form of safety lamp should be used exclusively in the mine. At the surface, the most improved ventilating apparatus should be in use. This should consist of duplicate sets of ventilating fans and engines, the

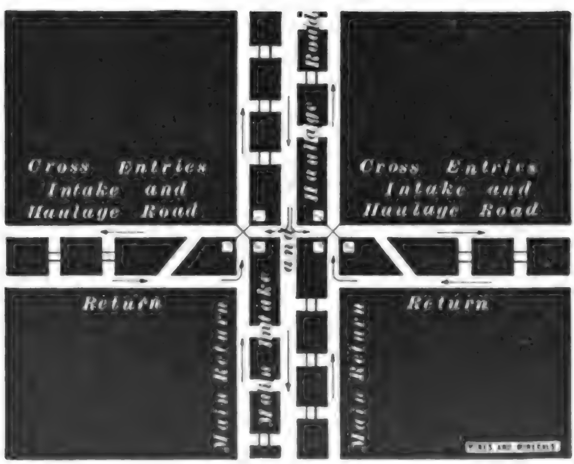


FIG. 4

former consisting of any of the improved types of centrifugal fans. The fans should be run as exhaust fans, but should be capable of being converted into blow-down fans if the emergency requires. These duplicate fans and engines should be run alternately to relieve each other, one fan and engine always being held in reserve for use in case of a breakdown. The fans should be set a sufficient distance back from the shaft to insure safety, and explosion doors should be provided over the shaft. There should be a good lamp station where the safety lamps can be cleaned. There should be a self-registering barometer and water gauge at the mouth of the mine.

QUES. 1362.—In the three-entry system driven to the rise, a considerable quantity of gas is being given off; show by sketch how the same can be ventilated to give good results. *I.—Pa. (B)*

ANS.—The sketch Fig. 4 shows a method suited to this case.

Ques. 1363.—What are the disadvantages of the triple-entry system of ventilation in a high seam of coal with a good roof?

M.—Ill.

Ans.—Assuming that the height of the entries is equal to the thickness of the seam, the triple-entry system of ventilation would require a large amount of air in circulation in order to maintain a proper velocity of the air-current in the entries. This, however, should hardly be classed as a disadvantage, since the triple-entry system of ventilation is particularly adapted to gaseous mines where a large quantity of air is required to dilute the gas produced in the workings. The expense of driving three entries instead of a pair of entries increases the cost of development.

PLANS OF MINE-VENTILATION SYSTEMS

Ques. 1364.—Make a sketch of a longwall mine, ventilated for 350 men and 28 mules, with stables at the bottom of shaft.

M.—Ill.

Ans.—The sketch shown in Fig. 5 is that of a longwall mine with stables located in the pillar at the shaft bottom, between the downcast and

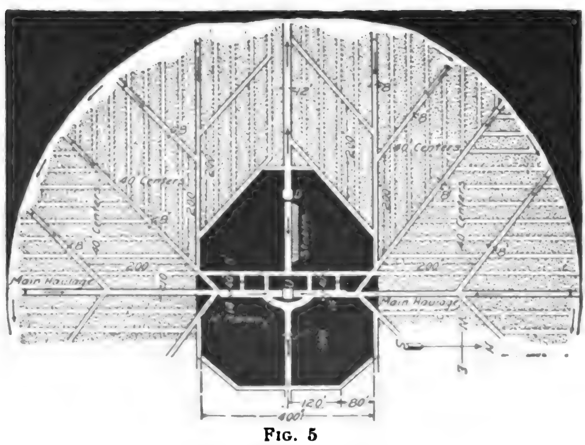


Fig. 5

the upcast shaft, which is the main hoisting shaft. The direction of the arrows shows the circulation in the mine. The quantity of air in circulation as required by law being

$$100 \times 350 + 600 \times 28 = 51{,}800 \text{ cu. ft. per min.}$$

This circulation is divided into four equal splits.

Ques. 1365.—A slope having been sunk on the Mammoth seam on a dip of 25°, on which it is proposed to work two lifts at one time, tunnels have been driven, cutting the Holmes, Primrose, and Orchard seams on the one side, and Skidmore and Buck

Mountain seams on the other side; what system would you adopt to ventilate the workings? Where and on what seams would you place the fan or fans? *F.—Pa.* (*A*)

Ans.—The main slope in the Mammoth seam will be the hoisting slope for the output of all the seams. To avoid the dangers of ignition of gas, this slope should be ventilated by an intake current. The ventilation of this mine can best be accomplished in three currents, and it will be best to provide three exhaust fans capable of throwing, say 150,000 cu. ft. of air per min. One fan may be located, Fig. 6, at the mouth of an airway driven on the Holmes seam, and ventilate this seam and the Mammoth. Another fan may be located at the mouth of an airway driven in the Skidmore seam, and ventilate this seam and the Buck Mountain seam. Likewise, a third fan may be located at the mouth of an airway driven in the Primrose seam,

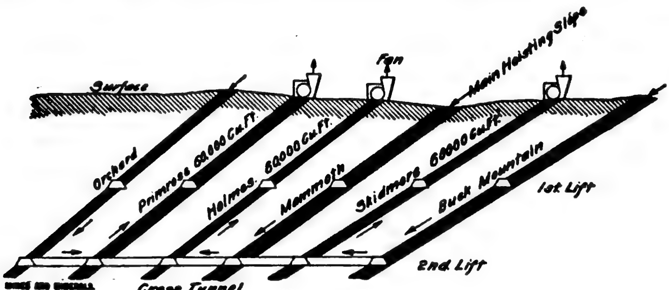


Fig. 6

and ventilate this seam and the Orchard seam. There are two methods, either of which may be adopted in the two last-named circulations. In one plan, intake airways may be driven in the Buck Mountain and Orchard seams, thereby making each circulation independent of the others. In another plan, instead of driving intake airways in the Buck Mountain and Orchard seams, the intake air for each may be taken down airways driven in the Mammoth seam, one on either side of the main slope. Regulators, to be used only in case of emergency, should be placed on the intake airways of the Orchard and Buck Mountain seams for the purpose of combining the three ventilators so as to work on a single current if needed. Likewise, also, regulators may be placed, to be used only in case of emergency, at the mouth of the lifts on the Mammoth seam, so that they will not interfere with the hoisting on the main slope.

Ques. 1366.—Describe the method of ventilating any large coal mine, with which you are familiar, and state how, in your opinion, it could be improved upon. *I.—Pa.* (*A*)

Ans.—Fig. 7 shows a system of ventilation that is frequently used, in which the air-current is conducted around the entire working face of one section of a mine, passing through the cross-cuts or break-throughs between the rooms. This system has the disadvantage of carrying all the gas and

smoke from one breast to another, and should never be used in a very gaseous seam. Another method is to supply each breast or group of six or eight breasts with fresh air from the gangway, conducting the air up the manway on one side of the breast, and down the other side, returning the current to the return airway; or if the air is taken from an airway driven above the gangway, the air from the breasts is returned into the gangway at once. In this way, each breast or group of breasts will be provided with its own circulation, and will be safer.

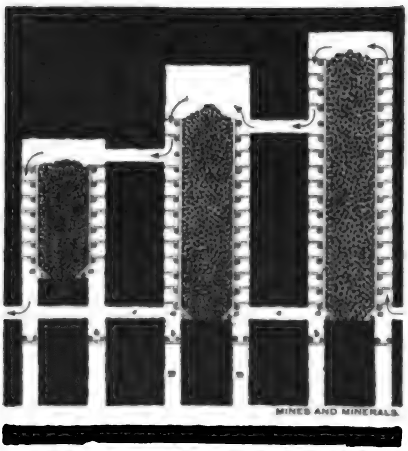


FIG. 7

QUES. 1367.—Give the plan or system of ventilation in use in some mine in which you have worked, also give name of mine. *F.—Pa. (A)*

ANS.—In the ventilation of many steep pitching anthracite seams, a small monkey airway *c*, Fig. 8, is driven in the top bench of the seam

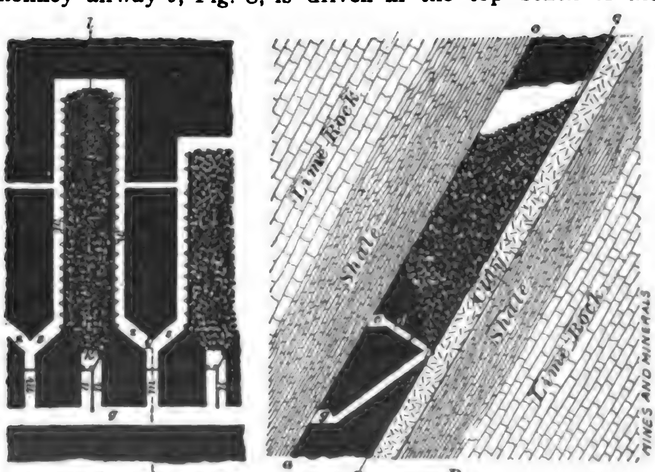


FIG. 8

above the main level *g*. The main gangway is made the intake, the air being conducted along the gangway to the inner face and returned along the face of the breasts by means of the monkey airway, which is connected with each breast by a short cross-cut *d*, near the foot of the manway.

CHAPTER XV

OPENING A MINE

MINE OPENINGS

QUES. 1400.—What is a slope? A drift? A plane?

F.—Pa. (*A*)

ANS.—A *slope* is any inclined mine opening or passageway driven in, or from the surface to, the seam, or underground from one seam to another; if this passage is driven through rock, it is called a *rock slope*.

A *drift* is a practically level passageway driven in the seam itself, usually from the surface. A drift is always driven with a sufficient rise to insure good drainage from the face to the mouth of the drift.

A *tunnel*, in coal mining, is any level passageway driven from the surface to an inclined seam, or from one seam to another, through the intervening strata; it differs from the drift only in not being driven in the seam itself.

A *plane* is usually understood as any form of haulage incline such as an engine plane or a gravity plane.

QUES. 1401.—How are the various mine openings designated and in what do they differ from one another?

ANS.—The several forms of mine openings are designated as shafts, slopes, drifts, and tunnels. A *shaft* is generally understood to be a vertical opening sunk from the surface to the seam or from one seam to another; in the latter case the shaft is often called a *blind shaft*.

A *slope* is an inclined opening or passageway driven either to the rise or to the dip, the latter being often called a plane. A slope may be driven in the seam or across the measures to the seam it is intended to reach; in the latter case it is called a rock slope; steeply inclined slopes are sometimes called inclined shafts, or simply shafts.

A *drift* is a practically horizontal opening in a seam; it differs from the slope only in being horizontal, or nearly so. A drift is driven with a slight upward grade to provide drainage.

A *tunnel* in coal mining is a horizontal opening driven across the measures to the seam that it is intended to develop or to drain, and differs from the drift only in the fact that it is driven across the measures while the drift is driven in the seam itself; a tunnel is sometimes called a stone drift.

SELECTION OF OPENING

Ques. 1402.—What are the forms of openings commonly used in Alabama mines? Describe conditions under which each of these can best be used. *F_2.—Ala.*

Ans.—The common forms of mine openings are shafts, slopes, drifts, and tunnels. Shaft openings are suited to comparatively deep-lying seams that do not outcrop on the property, whether these seams are flat or inclined. Steep inclined seams that are more or less broken or irregular are often better reached by a vertical shaft and a series of cross-cuts driven from the shaft to the seam at different depths. Slope openings are suited to shallow flat seams not outcropping on the property but from which it is proposed to mine a large daily output, and to inclined seams outcropping on the property at a point affording good shipping facilities and the necessary yard room for the surface plant. In shallow seams, a slope opening possesses a great advantage over a shallow shaft opening, as the depth of the shaft does not permit great speed of hoisting. Drift openings are used in flat seams outcropping on the property and in some inclined seams outcropping on a hillside at an available point for shipping and the erection of a surface plant. Stone drifts or tunnels are used to reach seams that do not outcrop on the property at a convenient point for shipping and the erection of a surface plant. Tunnels are also used for the drainage of inclined seams in mountainous districts.

LOCATION OF OPENING

Ques. 1403.—Where would you place a shaft in opening out a coal field in which the seam has an inclination of from 3° to 4°, and considerable water is expected? State your reasons.
F.—Pa. (A)

Ans.—In order to take advantage of the assistance offered by gravity, in haulage and drainage, the shaft should be located as far to the dip of the seam as surface conditions will permit. In the location of any shaft, the surface conditions must always be considered in connection with the conditions in the mine. The surface conditions to be considered, briefly stated, are: the position with respect to shipping facilities; the configuration of the surface, as affording sufficient level area for the necessary buildings; the existence of surface obstacles; proximity to towns or markets; and, lastly, the strata to be passed through in sinking. The underground conditions to be considered are haulage, drainage, location of faults, extent, thickness, and quality of coal. The first two conditions are, practically, dependent on the inclination of the seam.

SIZE OF OPENING

QUES. 1404.—What are the conditions that would determine the size of a shaft you are about to sink? *M.—Ill.*

ANS.—The size of a shaft will depend on the use to which it is put. A pump shaft should afford ample room for installing the pipe lines and performing the necessary work in the shaft after making due allowance for a manway. An air-shaft should have such a sectional area as to provide for the required circulation of air at a velocity varying from 20 to 50 ft. per sec. The velocity of air in a furnace shaft is much higher than this, but the volume of the air is expanded in the same proportion, requiring the same area in the shaft. It is always desirable, however, when sinking a shaft for any purpose, to consider as well as the present intended use, other possible uses of the shaft that may arise in the future working of the mine. For example, when sinking a prospect shaft, pump shaft, or air-shaft, the possibility of such shaft being available later as a hoisting shaft should be duly considered in determining its size. The size of a hoisting shaft is determined by: (1) the output required, depth of shaft, and character of the hoisting equipment, as determining the weight of coal per hoist and speed of winding; (2) thickness of seam, character of the roof, floor, and coal, as determining the size and shape of the mine cars. In a thin seam, low, flat cars are required, while a bad roof or floor will necessitate narrow openings and long, narrow cars; the size of the cars practically determines the size of hoistway required. A balanced hoist requires two hoistways, besides which a pump or manway should be provided. A generous allowance should be made for the clearance of the cars in the shaft. Although any increase in the size of the shaft means a larger excavation and a greater outlay, it is never advisable to curtail the size of the shaft on this account, inasmuch as a tight shaft is always an annoyance and expense in the working of the mine. The possible accumulation of ice in a hoisting shaft is also a factor that must be considered in the amount of clearance to be given the cage and cars.

QUES. 1405.—How many cubic yards of earth have been excavated from a shaft 37 feet long, 12 feet wide, and 750 feet deep? *F.—Pa. (A)*

ANS.— $$\frac{37 \times 12 \times 750}{27} = 12{,}333\tfrac{1}{3} \text{ cu. yd.}$$

QUES. 1406.—How many cubic yards of rock were removed from a shaft 10 ft. 6 in. × 8 ft. 9 in. and 241 feet 3 inches deep? What did the work cost at 15 cents per cubic foot? *F.—Pa. (A)*

ANS.— 10 ft. 6 in. = 10.5 ft.; 8 ft. 9 in. = 8.75 ft.; 241 ft. 3 in. = 241.25 ft. The amount of rock removed was

$10.5 \times 8.75 \times 241.25 = 22{,}165$ cu. ft.; $22{,}165 \div 27 =$ **821 cu. yd.**
The cost of work was

$22{,}165 \times \$.15 = \$3{,}324.75$

SHAFT SINKING

QUES. 1407.—Explain how you would prepare to sink a shaft through ordinary ground, with no quicksand or water; showing, by means of sketches, the method you would adopt for handling the material brought out of the shaft, so as to secure a minimum of risk to the lives of the men employed. *I.—Ill.*

ANS.—Having selected the site for the shaft, the ground is first cleared and leveled for a space about the shaft. If necessary, suitable ditches for the drainage of surface water are dug. The heavy sills and cross-sills for the shaft tower having been framed are laid in position on the ground (Fig. 1), squared and leveled. These sills are usually raised a little above the general level of the surface, so as to provide sufficient protection against the drainage of surface water into the shaft. A foundation for the main tower sills and cross-sills is obtained by laying short cross-ties or sills beneath them, having first, if necessary, dug trenches to a sufficient depth for this purpose.

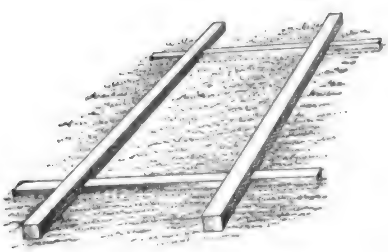


FIG. 1

The excavation is then begun, and carried down as far as practicable before inserting any lining, the distance depending on the nature of the drift or soil. The material is handled as shown in Fig. 2, during this stage of the sinking. The excavation is then squared up, and the permanent shaft timbers or curbing placed in position. The temporary sinking derrick is then erected above the shaft, as shown in Fig. 3. The derrick is made of such size as to stand within the permanent tower posts, as shown in the end view, Fig. 3, the purpose being that the permanent tower may be erected previous to the sinking being completed, and without interfering with the hoisting of material. The temporary tower stands over the hoistway, and an air stack of plain boards is constructed at the side over the

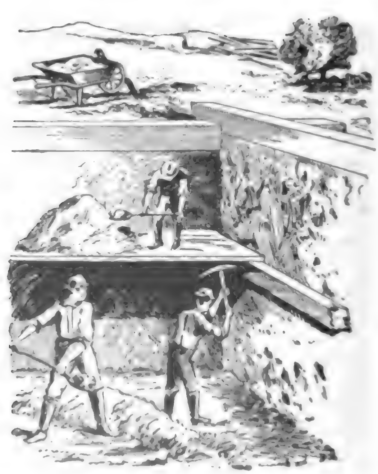


FIG. 2

manway, as shown in the figure. The hoisting engine used during sinking is placed at the end of the shaft in order that it may be out of the way of the arrangements for the permanent hoisting engine to be erected. The sheave over the temporary derrick is so arranged that the bucket hangs about the center of the entire shaft. An air-tight partition being carried down between the hoistway and the manway often provides sufficient ventilation of the shaft while sinking, without the introduction of steam

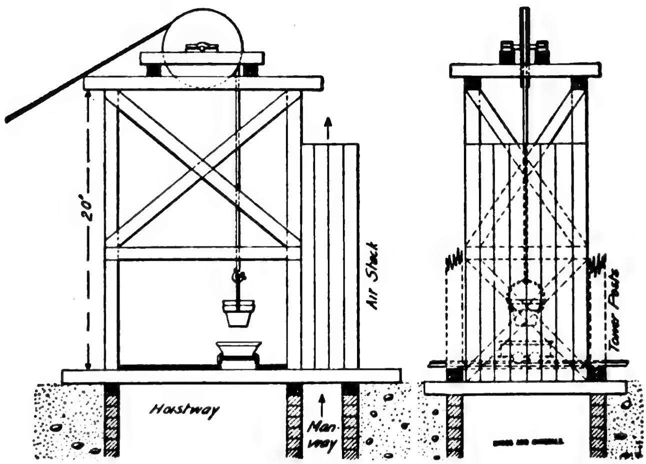


Fig. 3

jet or other artificial means. The mouth of the shaft over the hoistway is boarded over, except between the rails upon which the dump car runs. This is a low, flat car, having a wide gauge, and used for the purpose of running under the bucket when the same is hoisted. An empty bucket is in readiness upon the car, and the loaded bucket being lowered upon the car, the rope is detached and made secure to the empty bucket, which is then hoisted, and the car run out upon the dump.

Another arrangement, perhaps even more safe, since it allows of completely covering the mouth of the shaft, is to arrange the hoist in such a way that the ascending loaded bucket opens two flap doors as it passes through them, which fall back into position after the bucket has passed. These doors are arranged in an elevated position, as the roof of a house, so that they are opened readily by the ascending bucket. The rope passes through a hole cut in the center of the edges of the two doors; by this means the entire mouth of the shaft is kept covered. The bucket is hoisted to a somewhat higher position, and a snatch rope having been attached to the bail of the bucket, the load when lowered is swung clear of the shaft. The snatch rope is hung from a point somewhat outside of the derrick frame.

Ques. 1408.—How would you divide a shaft you were sinking, into the various necessary compartments, one compartment to be

used for water, air pipes, and ventilation until connection with the escapement shaft is made? Answer fully *M.—Ill.*

ANS.—In order to use one compartment of the shaft for ventilation, the partition separating this compartment from the rest of the shaft must be air-tight. Fig. 4 shows a line of heavy buntons dividing the shaft into two compartments. These buntons are set close to each other, and are heavy so as to resist the pressure upon the side of the shaft; they should be laid in cement or tar to furnish an air-tight joint. Where 3- or 4-in. timber is used, the partition is sometimes made air-tight by framing the bunton into the shaft wall plate by means of a groove and tenon joint. This, however, is expensive, and a cheaper and equally efficient partition can be made by using two layers of 2-in. planks, placing building paper between the layers and spiking them firmly to each other as they are put in. The joints in the planking should alternate with each other in the two layers.

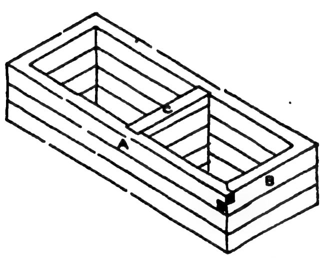


FIG. 4

COST OF SINKING

QUES. 1409.—If you were sinking a shaft 6 ft.×8 ft. and 75 feet deep, through material of moderate hardness, how many men would you employ, and what, in your opinion, should it cost per square foot for all things necessary? *F_1.—Ala.*

ANS.—It will not be convenient to work more than two sinkers below, in this size of shaft. In material of moderate hardness the average rate of sinking this shaft, allowing for delays, may be assumed as 1 ft. per day; it will probably somewhat exceed this amount. Following is an approximate estimate of the probable cost of sinking and timbering the shaft:

2 sinkers, 150 days each at	$ 3.00	$900.00
1 topman, 75 days at	2.00	150.00
1 engineer, 3 months at	60.00	180.00
Curbing, 8,000 ft. B. M.	12.50	100.00
Framing, 10 days at	2.50	25.00
8,000 feet of lumber at	15.00	120.00
Powder, drills, and sharpening tools		250.00
Incidentals		150.00
		$1,875.00
Contingencies, 10 per cent.		187.50
Total		$2,062.50

The cost of sinking and timbering this shaft will, therefore, be about $2{,}062.50 \div 75 = \$27.50$ per ft. in depth.

QUES. 1410.—State the probable cost complete of driving a tunnel $7\frac{1}{2}$ ft. × 9 ft. in the southern anthracite coal field, from the Primrose bed to the Skidmore bed—the measures pitching 30°. *I.—Pa. (A)*

ANS.—According to the sections of the State Geological Survey, the mean distance between the Primrose and Skidmore seams is 450 ft., and as the measures are pitching 30°, the length of the required tunnel will be

$$\frac{450}{\sin 30°} = \frac{450}{.5} = 900 \text{ ft. or } 300 \text{ yd.}$$

The average complete cost, per linear yard, for driving a tunnel $7\frac{1}{2}$ ft. × 9 ft. will not be less than $40 for hand drilling and, therefore, the total cost of the tunnel will be 40×300 = $12,000. If compressed air were at hand to run the drills, this cost would be reduced to possibly one-half this amount, but it would not pay to install a plant for this work only.

SECOND OPENING

QUES. 1411.—How many tons of mine run coal may be removed from a mine before a second outlet is required by law, allowing that each cubic yard of coal will weigh a ton and making no deductions for impurities? *F.—Ind.*

ANS.—The Indiana Mine Law, as revised by the Act of March 6, 1885, prohibits the employment of more than ten persons in any mine after 5,000 square yards have been excavated until a second opening is made. Assuming the thickness of the seam to be $5\frac{1}{2}$ ft. the number of tons that may be removed before a second outlet must be made is,

$$\frac{5{,}000 \times 9 \times 5\frac{1}{2}}{27} = 9{,}167 \text{ T.},$$

assuming that 1 cu. yd. of coal weighs 1 T. This does not, however, allow for any loss of coal in mining, which loss may amount to anywhere from 2 to 3 per cent. of the entire weight of coal mined.

QUES. 1412.—In providing a second outlet for the mine described in Ques. 1411, which would you prefer, a shaft or a slope? Give reasons for such preference; also describe your method of sinking and timbering each, giving difference in cost. *F.—Ind.*

ANS.—The preference for a shaft or slope as a second opening depends on the conditions under which the mine is to be operated. A slope may furnish a traveling way for men and animals but is often objected to as permitting the men to go and come at all hours of the day and night, and to that extent interfering with systematic regulations in regard to working hours. The same objection may be urged against a shaft fitted with a manway. In general, a shaft would be preferred for a second opening at a depth of 100 ft., when the seam is flat or does not outcrop. A shaft may

be sunk cheaper than a slope for any given depth below the surface, and furnishes better facilities for ventilation and pumping, being the shortest and most direct means of reaching the seam from the surface. The methods of sinking and timbering a slope in a slightly inclined seam are much the same as those employed in entry driving and are dependent on the character of the strata passed through. When the strata are soft, timbering is needed and the slope is advanced by cutting and blasting at the face in the usual manner. When the material is very soft and runs, the method by overpoling must be resorted to at the face. Timber frames are set from 3 to 4 ft. apart throughout the entire length of the slope, and lagging placed over these and at the sides to prevent caving. The size of timbers used will vary from 6 in. to 8 in. in diameter, according to the character of the strata and the depth from the surface. The legs of the framing sets should incline inwards at the top with a batter of about 2 in. to the foot. In overpoling, the timber frames are set close to the face and sheathing is driven over these frames toward the face to prevent the caving of the roof strata as much as possible. In sinking a rock slope, little or no timber is required.

In shaft sinking, the excavation through the surface drift is made with pick and shovel until hard pan is reached, when blasting is begun. Inclined or sumping holes are first drilled in the center of the shaft bottom. These holes are blasted first, so as to give charges in the more vertical holes immediately back of these an opportunity to perform their work. The different methods of shaft timbering are given in Chapter XVIII. The cost of sinking a slope in a seam of coal is practically the same as that of entry driving, and will vary fom $2 to $3 per yd., or will approximate $1 per ft. For sinking a rock slope, the cost will vary from $2 to $5 per ft. for each 50 sq. ft. of cross-section, according to the character of the material. The cost of shaft sinking is greater, and will vary according to the material, from $5 to $40 per ft. in an ordinary size shaft, when the excavation is about 8 ft. × 18 ft. The cost for shafts of smaller dimensions is somewhat increased on account of the limited space for the workmen, and the cost for larger shafts will increase according to the amount of material to be handled. These figures will usually cover the cost of framing and timbering.

Ques. 1413.—After opening the mine referred to in the preceding question, we have decided to provide a slope for a second outlet, and we find that by beginning at the bottom and driving up, we can do the work much cheaper. We wish to begin at a point away from the shaft and drive the slope up toward it. The slope must be driven with a grade of 25 per cent. and reach the surface at a point 100 feet from the hoisting shaft, measured in the direction of driving. How far from the bottom of the shaft must the slope be commenced? *F.—Ind.*

Ans.—The surface being level and the seam flat and lying at a depth of 100 ft. from the surface, the depth to the floor of the seam is 100 + 5.5 = 105.5 ft. The grade of a shallow slope is usually estimated as a

percentage of its horizontal length; thus, a 1-per-cent. grade means a rise of 1 ft. in each 100 ft. of horizontal distance, and a grade of 25 per cent. means a rise of 25 ft. in each 100 ft. of horizontal distance. The horizontal distance in which a slope having a grade of 25 per cent. will rise 105.5 ft., is $105.5 \div .25 = 422$ ft. And since the slope is to reach the surface at a distance of 100 ft. from the mouth of the shaft, $422 + 100 = 522$ ft. is the total distance of the foot of the slope from the bottom of the shaft.

QUES. 1414.—The owner of a certain mine intends sinking a shaft to be used as a second outlet or manway. The shaft will be 6 ft. × 8 ft. in size, and 95 feet deep; the strata to be sunk through are as follows: fifteen feet of hard pan, 45 feet of sandstone, 35 feet of gray slate. Which do you think will be the cheaper method, to sink it from the top, or drive it up from the bottom? Give reasons in full for preference, showing advantages and disadvantages of each plan. *F.—Ind.*

ANS.—The comparative cost of sinking or upraising will depend on the level conditions. In upraising, the material excavated must be stowed in abandoned workings, or transported to the foot of the shaft and hoisted to the surface. The operation of upraising, considered by itself, is in general cheaper than that of sinking, for the reason that the material is handled by gravity, pumping is obviated, and lighter shots are required in the work of excavation; but the disposal of the material will add very largely to the expense of upraising if this cannot be done near at hand in the mine workings. The advantages in favor of sinking are that the material excavated is usually easily disposed of at the surface; there is less delay in clearing the smoke when blasting than in the operation of upraising, and ventilation is easier.

QUES. 1415.—How should a second opening or escapement shaft 400 feet deep be equipped? *F.—Pa. (A)*

ANS.—The Anthracite Mine Law of Pennsylvania requires that all escapements, shafts, or slopes, shall be fitted with safe and available appliances, by which the persons employed in the mine may readily escape in case an accident deranges the hoisting machinery at the main outlet.

OPENING UP A MINE

QUES. 1416.—In opening up a colliery, what precautions would you use for the future protection of your slope or shaft? *F.—Pa. (A)*

ANS.—Ample pillars should be left in the seam, surrounding the shaft or flanking the slope. The size of the shaft or slope pillars will be determined by the depth of the shaft or the cover overlying the slope. The thickness of slope pillars should increase with the depth.

QUES. 1417.—In the opening and development of a new mine, what are the most serious questions to be considered? *F.—Ind.*

ANS.—Before opening a mine the following questions should be carefully considered: (1) where the output will be marketed; (2) facilities of transportation to the market and the market value; (3) competition of other mines with respect to quality and price; (4) cost of operating and transporting to market, per ton of output—this cost should include the entire operating expenses of the mine, including cost of mining, dead work, drainage and ventilation, handling of the coal from the working face to the market, supplies, office expenses, superintendence and management, royalties, insurance, interest on investment, and sinking fund; (5) the labor required for the operation of the mine; (6) the extent of the coal field held or controlled by the company operating the mine. In the development of a new mine, it is important to decide upon: (1) the kind of opening—shaft, slope, or drift; (2) the location of the opening; (3) the method of working or the general plan of the mine; (4) the system of haulage or manner of handling the coal from the face to the shaft or slope bottom; (5) the plan of ventilation of the mine workings; (6) the drainage of the mine; (7) the manner of mining the coal and the use of machines at the face, the explosives to be used, manner of placing shots, support of roof at the face, width and direction of rooms, size of pillars, etc.

QUES. 1418.—What arrangement would you make at the bottom of the hoisting shaft to handle 600 tons of coal per day, and how many men would such an arrangement require to cage that amount of coal? *M.—Ill.*

ANS.—If the coal is received on one side of the shaft only, the shaft bottom may be arranged as shown in Fig. 5. The loaded track is slightly

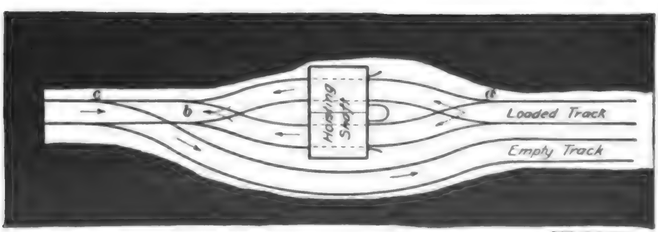


FIG. 5

elevated above the empty track and has a grade of 1 to 1.5 per cent. toward the shaft, to expedite the handling of the loaded cars. The loaded track, as shown in the figure, is in line with the center of the shaft, the switch *a* allowing the cars to pass to either cage. The loaded car bumps the empty off the cage, and the latter, passing down a short, steep grade and through the switch *b*, runs up a short incline called a kick-back; then returning through the spring switch *c*, it runs by gravity around the shaft to the empty track. Sometimes the empty car passes through a crossover to a

separate entry where the empty track is located. By this arrangement, one man with the assistance of a boy to couple the empty cars, can cage 600 T. of coal per day. The boy, when necessary, can sprag and assist in moving the loaded cars. If the coal is received on both sides of the shaft, there will be a loaded and an empty track on each side in line with each cage, the loaded track on one side being opposite the empty track on the other side of the shaft. As before, the loaded car bumps the empty off the cage. In this arrangement, a man can cage all the loads of a single trip on one side of the shaft, while a boy takes off the empties on the opposite side; but this will require cross-caging, and the man and boy will have to change places when caging the loaded trip on the other side of the shaft. When there is no cross-caging, but cars are caged alternately on opposite sides of the shaft, two men will be required instead of a boy and a man.

Ques. 1419.—Describe how you would lay out and proceed to develop a large mine with a view of insuring the greatest degree of safety to the workmen and securing the greatest percentage of coal from the property, the coal seam lying at a depth of 300 feet from the surface, with ordinary conditions with regard to roof and floor. *F.—Pa. (A)*

Ans.—Assuming that the shafts have been properly located and sunk so as to afford the greatest advantage in respect to haulage, ventilation, and drainage, the next step is to put in the heavy sump timbers and the framing to support the shaft lining. The main entries should then be started and driven square with the shaft. The shaft bottom should be made of such dimensions as will afford the best facilities for handling and caging the coal, and the grade of the empty and loaded tracks should be such as to facilitate the movement of the cars. The shaft pillars should be of sufficient size to insure the protection of the shaft. As the mine is to be a large one and the maximum of safety is to be provided for the workmen, and the highest possible percentage of coal to be taken out, the mine should be worked by the panel system, especially if gas is present in the seam. Care should be taken in beginning the development of the workings to leave strong barrier pillars between the first panels opened out, and not only to make the pillars in these wider than will be necessary in the inner panels, but to leave them unrobbed until the inby coal has all been extracted. By this method of proceeding, the roads leading to the shafts can be kept in order and repaired at less expense, and a higher percentage of the coal can be secured at a lower working cost, and with a maximum of safety to life.

Ques. 1420.—We own a tract of land several hundred acres in area, which is underlaid with a vein of bituminous coal 5½ feet thick, at a depth of 100 feet from the surface. The vein is overlaid with a gray shale roof of good quality, and is underlaid with a hard sand grit bottom. We wish to open a mine on this tract

of land which will insure us an output of 1,200 tons a day, and at the same time win out or remove as large a percentage of the coal from the seam as is consistent with good mining. Describe, in full, how you would open and equip this mine to secure these results, beginning with size of shaft, shaft bottom, shaft pillars, plan of workings, width of entries, rooms, room pillars, size of mine cars, tracks, mode of ventilation, etc. *F.—Ind.*

Ans.—The size of a hoisting shaft depends on the size of the mine car to be used; the size of the mine car is determined by the output and the number of cars that it is possible to hoist in a given time (say 1 hour), and is modified by the thickness of the seam and the kind of roof and bottom, since in thin seams low, shallow cars will be required, and with frail roof or soft bottom narrow cars are often necessary. At a depth of 100 ft. possibly three hoists could be made per minute; it will be better, however, to estimate on two hoists per minute to determine the size of the shaft required. This will make due allowance for necessary delays and give for the weight of coal per hoist, for an output of 1,200 T. in 10 hours,

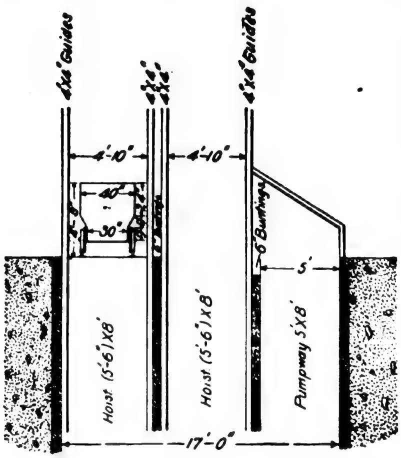


Fig. 6

$$\frac{1{,}200}{10\times 60\times 2} = 1 \text{ T. per hoist}$$

One ton of bituminous coal (broken) occupies from 43 to 48 cu. ft., according to the character and size of the coal, say in this case 45 cu. ft. The thickness of the seam being 5½ ft., a car similar to that shown in Fig. 6 may be adopted, reducing the height of the upper portion of the car from 24 in., as indicated, to 16 in. If this car is then loaded 6 in. above its top, the area of cross-section of the coal will be 9 sq. ft., and the inside length of the car for a capacity of 1 T. (45 cu. ft.) $45 \div 9 = 5$ ft. Allowing 18 in. at each end of the car beyond this dimension for bumpers and clearance in the shaft, the full width of the shaft in the clear is $5+3 = 8$ ft. The length of the shaft will then be, as shown in Fig. 6, making each hoistway (5 ft. 6 in.) × 8 ft., and providing a manway or pumpway of 5 ft. × 8 ft. This makes the full size of the shaft, in the clear, 8 ft. × 17 ft.

Assuming a flat seam, the shaft bottom should be driven each way from the foot of the shaft with a width of not less than 14 ft. in the clear between timbers, for a distance of say 60 yd. or more from the shaft, on each side. The grade of the shaft bottom should be from 12 to 18 in. per 100 ft. toward the shaft, that is, in favor of the loaded car. A general arrangement for the shaft bottoms, main haulage roads, air-courses, stables,

cross-entries, and rooms and the plan of ventilation are shown in Fig. 7. The width of the main haulage roads and of the cross-entries should not be less than 8 ft., and the entry pillars on the main roads, say 5 yd. for this cover, and on the cross-entries 4 yd. in width. Rooms are turned to the right and left of each pair of cross-entries, leaving a distance of 40 ft. from the main entry to the outside rib of the first room. The rooms are turned narrow, 8 ft. wide (if the coal is frail this width may be reduced to 6 ft. for a distance of 3 yd.), and are then widened on the inby rib at an angle of 45°. The roof and floor being hard and strong, breasts may be driven 27 ft. wide with 13 ft. pillars between them, making the distance from center to center of the rooms 40 ft. On account of the hard roof in this case, the room pillars should not be much less than 13 ft., even at this depth (100 ft.). The mine should be equipped with a good pair of 12 in. × 16 in. second-motion hoisting engines, having a 5-ft. drum supplied with a good brake; the shaft should be equipped with iron cages, guides, wings, safety gates, safety catches being used on the cages, etc. The ordinary form of tipple or dump may be used with upper landing, say 24 ft. above the railroad tracks, and supplied with the requisite nut and lump screens and track scales for weighing lump coal. There should also be erected a good ventilating fan, which can be used either as a blow-down or as an exhaust fan. This fan should be located at the second opening, or air shaft, at a distance not less than 100 ft. from the hoisting shaft.

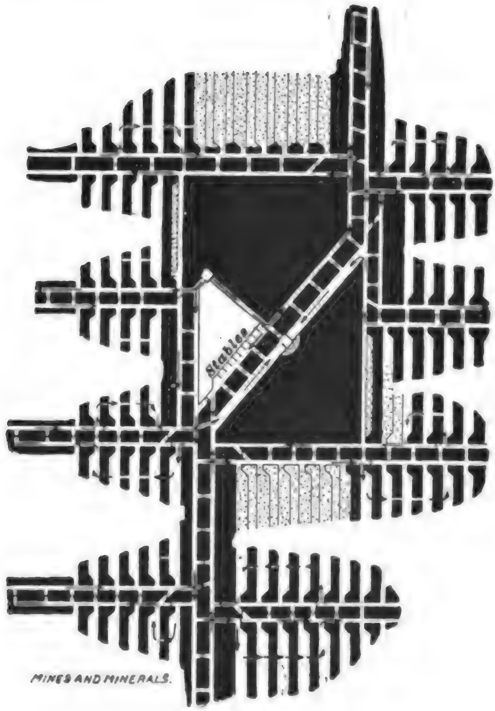


FIG. 7

QUES. 1421.—A certain coal seam underlying 2,000 acres must be reached by shaft openings; it has an average inclination from the southwest to the northeast of 1 foot in 150; state where you would make your openings, how many would be required, and the distance between them to comply with the mining law. State how you would lay out the workings of said coal field. What

apparatus would you recommend to produce the ventilation, and how would you conduct the air-currents; also, what method would you adopt to drain the water from the mine?

F.—Pa. (B)

Ans.—The location of the coal field with respect to the railroad will, in a general manner, determine the number and location of openings required for its development. These openings will preferably be located along the line of the railroad. The distance apart of the several shafts will be determined largely by the character of the roof, floor, and coal of the seam, since these factors determine the length of haulage roads that can be economically maintained. Where rope or motor haulage is employed under good conditions of roof, floor, and coal, the main haulage roads often reach a length of 3,000 to 6,000 ft., and in certain cases they are even longer. The territory to be reached from one shaft opening where the coal is evenly distributed around the shaft, is limited by the amount of coal that can be hoisted per day in the shaft. This depends on the size and depth of the shaft, the hoisting plant in use, and the size of the mine cars. In general, a double-compartment 8 ft. × 12 ft. hoistway, not exceeding 450 ft. in depth, will accommodate an output of 1,200 to 1,500 T. per day, or the product of about 600 rooms. In the regular development of such a mine, this limit of shaft capacity can easily be reached within a territory of 100 A.; and if the demand for coal, or the capacity for marketing the output warranted, a second shaft will then be sunk on another 100 A. adjoining the first. It will be a question, however, of demand and supply of coal, that will require another shaft upon an adjoining 100 A. If this demand for coal does not exist, it will be possible to reach and mine the coal economically from a territory of from 300 to 600 A., depending on conditions in the seam. In order to comply with the mining law, it will be necessary to maintain a connecting roadway or travelingway between adjoining shafts and such road or travelingway must be kept clear and free of all obstruction; or a second opening must be sunk for each new shaft. The distance required by law between the main shaft and the second opening must not be less than 150 ft.

The workings in each shaft should be laid out with respect to the extent of the coal field, in all directions around the shaft. The dip of the seam, 1 ft. in 150, giving a grade of .0067, is not sufficient to interfere seriously with haulage in any direction; and the course of the main haulage roads may therefore be determined by more important considerations, such as the extent of the coal field, the direction of cleats, if any, in the coal, or slips in the roof. Fans should be used for the ventilation of the mine, especially if gas is present in the coal. The double-entry or triple-entry system should be adopted, one entry of each pair or set being made the intake and the other or others the return for the air-current. The mine should be divided as far as practicable into separate districts for ventilation. Pumps should be used for the drainage of the mine, allowing all the water from the rise side of the shaft to drain into the sump at the shaft bottom. If necessary, another sump should be made in the dip workings

and reached by means of a drill hole from the surface, a pump being located at that point on the surface.

Ques. 1422.—On a tract of land extending 2 miles along the strike of measures, and having a width sufficient to afford six lifts, there are three beds of coal 3 feet, 6 feet, and 10 feet in thickness, respectively, and having an average north dip of 35°. All the beds outcrop. State how you would proceed to develop this property, and give the probable cost of erecting a plant to ship 700 tons a day, the topography of the surface being favorable for the erection of the breaker and other buildings. *I.—Pa. (A)*

Ans.—Assuming the 10-ft. seam to be the lowest of the three, the development should be begun by driving a slope and its airway in this seam. This slope, which should be driven on the full dip of the seam and extended to the boundary line, if possible, will furnish the haulageway for the output of the three seams. At the foot of the slope a cross-tunnel is driven, cutting the other two seams. From this cross-tunnel, gangways are driven to the right and left on the strike in each seam. The chambers are then opened to the rise in the lowest seam first, and later in the overlying seams, always taking care that the breasts in the lower seams are kept from 12 to 15 yd. in advance of those above them. The breasts should be vertically over each other, and the pillars the same. The pillars in the upper seams should be drawn first. The chambers are worked to the rise for a distance of 100 yd. or less, depending on the nature of the roof and floor. Other lifts are opened above this from the slope by driving a new cross-tunnel, and are worked in the same manner. This method of working is applicable when the parting between the seams exceeds 4 or 5 ft. When the parting is less than 4 ft., the seams may be worked together by dropping this parting as the lower chamber is advanced, the coal above being brought down much more cheaply than it otherwise could, the miners standing on the refuse of the seams or partings.

An approximate estimate of the cost of a plant for shipping 700 T., where the topography of the surface is favorable for the erection of the breaker and other buildings, will be $100,000.

Ques. 1423.—Assume that you are put in charge of the following field to develop and operate: The output is not expected to exceed 500 tons per day; a railroad runs east and west along the southern edge of the field; about 40 feet from the track the land rises in a bluff 50 or 60 feet in height, and the field lies north of the bluff and consists of some 600 acres, more or less. On the western line the coal is 40 feet from the surface, and on the eastern line of the property, where the surface is 9 feet higher, it is 25 feet to the coal. The true dip of the coal is on a line N 85° W. The roof is a strong slate that seldom breaks; the coal is 5½ feet in

thickness, and is of such a character that it will sometimes take fire spontaneously when left as slack in damp heaps. There is not a great deal of water in the field, but some is to be looked for all through the workings. How would you proceed to open out this field? In what direction, would you drive your main entries; in what direction would you drive your cross-entries and rooms? What size of entries and rooms would you drive, and what size of pillars would you leave on the entries and between the rooms?

ANS.—The quantity of water being small, it will be practicable to rely on the drainage afforded by local sumps provided at different points in the mine where required. These sumps are emptied by bailing or pumping into water cars, or as the cover is light, if desired, bore holes may be sunk from the surface through which to pump the water, as found most practicable. The chief points to be considered in deciding on the general plan of this mine are the inside haulage and the tipple arrangements at the mine opening. Assuming the coal tract to be square, the width of the field from east to west will be approximately 5,100 ft. or 1,700 yd. The coal at the western line is $40-(25-9) = 24$ ft. lower than at the eastern line, and the dip from east to west is therefore

$$\frac{24 \times 12}{1{,}700} = .17 \text{ in. per yd.}$$

This inclination is so slight as not to affect the movement of coal on the roads or in the rooms.

The direction of driving the entries and rooms is determined by the working character of the coal, direction of cleats, etc. Since these are not mentioned, the main pair of entries should be driven from the outcrop in the bluff, due north through the center of the field. From these main entries, cross-entries may be driven in pairs east and west every 100 or 150 yd., leaving a block of coal 300 to 500 ft. wide between each pair of cross-entries. Rooms are then driven north and south off these cross-entries.

All entries should be driven 8 ft. wide; the main entry pillars should be 8 yd., and the cross-entry pillars 6 yd. in width. The rooms are turned narrow for a distance of 3 yd. from the entries and then widened out to a width of 8 yd., leaving pillars 3 or 4 yd. wide between them. The fine coal and slack should all be loaded out. When the pillars are pulled back, all timbers should be withdrawn or destroyed so as to cause a fall of roof. The tipple arrangements at the opening will depend on the sizes of coal desired. For lump, nut, and steam coal, the width of 40 ft. will not furnish more than side-track room. The outcrop of the coal in the bluff at the center line of the property being, say, 23 ft. above the railroad, will give ample height for clearance, so that the tipple tracks may be extended over and across the railroad track and allow the loaded trip to be pulled beyond the tipple. The chutes should then be arranged to dump back toward the mine opening. The cars are brought out of the mine tail-end first and dumping begins at the rear end of the trip.

QUES. 1424.—Describe, in detail, the plan of working, method of ventilation, and the arrangement and construction of haulage roads at one of the most successfully operated mines in which you have been employed. *F.—Ind.*

ANS.—The answer to this question, which is one frequently asked, depends entirely on the practice in any particular section of country The question must therefore be answered according to a person's experience.

LEGAL REQUIREMENTS REGARDING SHAFTS

QUES. 1425.—State the requirements of the law on shaft sinking. *F.—Pa. (A)*

ANS.—The Anthracite Mine Law of Pennsylvania provides as follows:

Over all the shafts which are being sunk a safe and substantial structure shall be erected as soon as a substantial foundation is obtained to sustain the sheaves or pulleys at a height of not less than twenty (20) feet above the tipping place and the top of such shaft shall be arranged in such a manner that no material can fall into the shaft while the bucket is being emptied.

In no case shall a shaft be sunk to a depth of more than fifty (50) feet without such structure.

All rock and coal shall be raised in a bucket, or on a cage, while a yoke must be connected to the rope or chain by a safety hook, clevis, or other safe attachment.

Shafts over 100 feet deep shall be provided with guides to within 75 feet of the bottom to prevent the bucket from swinging while descending or ascending.

Where the strata are not safe every shaft shall be securely lined.

The following rules shall be observed as far as practicable.

First. After each and every blast, the chargeman must see that all loose material is swept down from the timbers before the workmen descend to their work.

Second. After a suspension of work and also after firing a blast in a shaft where explosive gases are evolved, the person in charge must have the said shaft examined and tested with a safety lamp before the workmen are allowed to descend.

Third. No more than four persons shall be lowered or hoisted in any shaft on a bucket at the same time, and no person shall ride on a loaded bucket.

Fourth. Whenever persons are employed on platforms in shafts the person in charge must see that the said platforms are properly and safely constructed.

Fifth. While shafts are being sunk all blasts therein must be exploded by an electric battery.

Sixth. Every person who fails to comply with or who violates the provisions of this article shall be guilty of an offense against this act.

QUES. 1426.—What are the requirements of the Mine Law as to one or more shafts? *M.—B. C., Canada*

ANS.—Section 24 of the Mine Law makes it unlawful for any person to be employed in or to enter any mine for the purpose of employment therein unless there are in communication with every seam of such mine at least

two shafts or outlets, separated by not less than 10 ft. of natural strata. Such shafts or outlets to provide separate and distinct means of ingress and egress that will be available to the persons employed therein; provided also that said two shafts or outlets may belong to the same or to different mines. The section also provides that there shall be a communication not less than 4 ft. wide and 3 ft. high between said two shafts or outlets, and that there shall be at each of said shafts or outlets, proper apparatus for raising and lowering persons, and they shall be either in actual use or available for use within a reasonable time.

NOTE.—Each state has its own regulations upon this point, and while these regulations are quite similar in the different states, the exact answer here given applies only to British Columbia.

QUES. 1427.—Give the law in regard to air and escape shafts. *I.—Ia.*

ANS.—Chapter 9, Section 2486, of the Iowa code requires the construction and maintenance of at least two distinct openings for each seam of coal worked by a shaft, slope, or drift opening. These openings, in the case of shafts, to be separated by not less than 100 ft. of natural strata, and in the case of slopes or drifts by not less than 50 ft. The ingress and egress of employes through these openings shall be unobstructed. Slope or drift openings shall be provided with safe and available travelingways free from water and falls of roof. Shafts not provided with proper hoisting appliances shall be supplied with stairs at an angle not greater than 60°, and be kept in safe condition, with proper landings at easy distances apart. No combustible material shall be allowed between any escape shaft and hoisting shaft, save as it may be absolutely necessary in the operation of the mine. A furnace shaft, if large enough, may be so divided as to contain a manway or escape shaft, the partition being of non-combustible material for a distance not less than 15 ft. up from the bottom of the shaft, and so constructed as to exclude heated air and smoke from the manway. The hoisting shafts or slopes of two adjoining mines connected underground, may, by mutual agreement of the owners of the mines, be used mutually in case of need as an escape from one or the other. An underground travelingway shall be provided at the top of all escape shafts separated from the hoisting shaft by a distance less than 100 ft., so as to furnish protection from fire for a distance of 100 ft. from said hoisting shaft. The mine inspector of the district must be notified before any escape shaft is located or constructed. No building, other than the fan house, shall be placed nearer than 100 ft. from an escape shaft.

QUES. 1428.—What are the requirements of the law in reference to escapement shafts? *M.—Ill.*

ANS.—Sec. 3 reads as follows:

(*a*) *Two Places of Egress.*—For every coal mine in this State, whether worked by shaft, slope, or drift, there shall be provided and maintained, in addition to the hoisting shaft, or other place of delivery, a separate escapement shaft, or opening to the surface, or an underground communicating passageway between every such mine and some other contiguous mine, such

as shall constitute two distinct and available means of egress to all persons employed in such coal mine. The time allowed for completing such escapement shaft or making such connections with an adjacent mine as is required by the terms of this Act, shall be three months for shafts 200 feet or less in depth, and six months for shafts less than 500 feet and more than 200 feet, and nine months for all other mines, slopes, or drifts or connections with adjacent mines. The time to date in all cases from the hoisting of coal from the main shaft.

(*b*) *Unlawful to Employ More Than 10 Men.*—It shall be unlawful to employ at any one time more men than in the judgment of the inspector is absolutely necessary for speedily completing the connections with the escapement shaft or adjacent mine; and said number must not exceed 10 men at any one time for any purpose in said mine until such escapement or connection is completed.

(*c*) *Passageways to Escapement.*—Such escapement shaft or opening, or communication with a contiguous mine as aforesaid, shall be constructed in connection with every seam of coal worked in such mine, and all passageways communicating with the escapement shaft or place of exit, from the main haulingways to said place of exit, shall be maintained free of obstruction at least 5 feet high and 5 feet wide. Such passageways must be so graded and drained that it will be impossible for water to accumulate in any depression or dip of the seam, in quantities sufficient to obstruct the free and safe passage of men. At all points where the passageway to the escapement shaft, or other place of exit, is intersected by other roadways or entries, conspicuous sign boards shall be placed, indicating the direction it is necessary to take in order to reach such place of exit.

(*d*) *Distance From Main Shaft.*—Every escapement shaft shall be separated from the main shaft by such extent of natural strata as may be agreed upon by the inspector of the district and the owner of the property, but the distance between the main shaft and escapement shaft shall not be less than 300 feet without the consent of the inspector, nor more than 300 feet without the consent of the owner.

(*e*) *Buildings on the Surface.*—It shall be unlawful to erect any inflammable structure or building in the space intervening between the main shaft and the escapement shaft on the surface, or any powder magazine, in such location or manner as to jeopardize the free and safe exit of the men from the mine, by said escapement shaft, in case of fire in the main shaft buildings.

(*f*) *Stairways or Cages.*—The escapement shaft at every mine shall be equipped with safe and ready means for the prompt removal of men from the mine in time of danger, and such means shall be a substantial stairway set at an angle not greater than 45 degrees, which shall be provided with handrails and with platforms or landings at each turn of the stairway.

In any escapement shaft which may, at the time of the passage of this Act, be equipped with a cage for hoisting men, such cage must be suspended between guides, and be so constructed that falling objects cannot strike persons being hoisted upon it. Such cage must also be operated by a steam hoisting engine, which shall be kept available for use at all times, and the equipment of said hoisting apparatus shall include a depth indicator, a brake on the drum, a steel or iron cable, and safety catches on the cage.

(*g*) *Obstructions in Shaft.*—No accumulations of ice, nor obstructions of any kind shall be permitted in any escapement shaft, nor shall any steam, or heated or vitiated air be discharged into said shaft; and all surface or other water which flows therein shall be conducted by rings or otherwise to receptacles for the same, so as to keep the stairway free from falling water.

(*h*) *Weekly Inspections.*—All escapement shafts and the passageways leading thereto, or to the works of a contiguous mine, must be carefully examined at least once a week by the mine manager, or a man specially delegated by him for that purpose, and the date and findings of such inspection must be duly entered in the record book in the office at the mine. If

obstructions are found, their location and nature must be stated, together with the date at which they are removed.

(*i*) *Communication With Adjacent Mine.*—When operators of adjacent mines have, by agreement, established underground communication between said mines, as an escapement outlet for the men employed in both, the roadways to the boundary on either side shall be regularly patrolled and kept clear of every obstruction to travel by the respective operators, and the intervening doors shall remain unlocked and ready at all times for immediate use.

When such communication has once been established between contiguous mines, it shall be unlawful for the operator of either mine to close the same without the consent both of the contiguous operator and of the State Inspector for the district. *Provided*, that, when either operator desires to abandon mining operations, the expense and duty of maintaining such communication shall devolve upon the party continuing operations and using same.

DRIVING TOWARD OLD WORKINGS

QUES. 1429.—What dangers are met in approaching old abandoned workings? What precautions should be taken to avoid those dangers? *F.—Ind.*

ANS.—There are liable to exist in such workings dangerous accumulations of water or gas, or both. If the pillar between the workings is allowed to get too thin, it will give way suddenly, permitting an inrush of water or gas into the workings that may drown or smother the men, drown out the mine, or wreck it by an explosion of gas.

FIG. 8

An examination should be made to ascertain the condition of the abandoned mine and to determine what head of water is liable to be encountered. Not more than one opening should be driven in approaching such workings and the width of the opening should not exceed 12 ft. Ventilation is maintained in the face by means of a brattice set about 2 ft. from the rib on one side, as shown in Fig. 8. Safety lamps only should be used at the face. Drill holes are bored in the face as shown in the figure, one hole being kept in the face at least 20 ft. in advance and in line with the entry, while flank holes are bored on each side in the rib each 8 ft. of advance, and making an angle of 25° or 30° with the line of the entry. In thick seams, it may be necessary to use two rows or banks of these holes. A sharp lookout must be kept by the workmen for any increase of water or gas, indicating proximity to danger, particularly along the floor and roof, and plugs should be kept in readiness for instant use in case a drill hole breaks into old workings and a rush of gas or water results.

QUES. 1430.—If you were about to tap a large body of water in an adjacent mine, how would you proceed to do so safely, and what

means would you adopt to satisfy yourself that the head of water was becoming considerably reduced? *F.—Pa. (B)*

Ans.—The men must first be withdrawn from the mine, as required by the Bituminous Mine Law of Pennsylvania, except only those engaged in the work. A narrow heading, 10 ft. wide, is then started and driven in the direction of the abandoned workings; a drill hole is kept drilled 20 ft. in advance of the face of the heading, and flank holes are drilled on each side of the heading, 8 ft. apart. Ample arrangements should be made beforehand for the drainage of the water from the heading. Before the water is tapped, accurate observations should be taken of the height at which the water stands in the adjoining mine, and the rate at which the level of the water falls below this should be carefully noted from time to time and the decrease in the head of water thus be told. The men should not be allowed to return to their places until the flow of water is considerably lessened and its head reduced. The bore holes will generally furnish a means of draining the water into the mine workings, whence it flows into the main sump and is pumped to the surface. Sometimes a pipe with a valve is inserted in the hole before it is drilled through the pillar, and after this pipe has been made secure a drill is passed through the pipe and valve and the hole completed. Pipes of considerable size may be inserted in this way, always using a gate or straightway valve to control the flow. A pressure gauge may be inserted in the pipe and the decrease in the head of water thus measured.

Ques. 1431.—Why is it that it is safer to approach accumulations of water under high pressure than accumulations under low pressure? *I.—Pa. (B)*

Ans.—There is, perhaps, greater security in approaching accumulations of water under a great head on account of the water making its appearance or giving evidence of its presence by seepage through the seam and strata quicker than would occur when the head of water was small and the pressure low. In general, more care and greater caution will be exercised by the men in approaching the larger body of water under the greater pressure, than when approaching the water under a comparatively low pressure. The elements of caution in regard to the measures adopted to prevent accident certainly give greater security, but it is questionable whether the actual danger is less in proximity to the greater head of water.

SURFACE ARRANGEMENTS

Ques. 1432.—Give a brief description of the surface arrangement of any large colliery, giving the location of buildings, dimensions of engines, number of boilers, size of ropes, breaker engines, fan, and the general arrangement of tracks for mine cars.

I.—Pa. (A)

Ans.—The surface arrangements of a certain large colliery are shown in Fig. 9. The hoisting engines *j* for shaft *d* are a pair of 28″ × 60″ direct-acting hoisting engines, with cast-iron grooved double-coned drum 19 ft. long, $8\frac{1}{2}$ ft. diameter at each end, and 14 ft. diameter at center. The hoisting engines *i* for shaft *c* have 32″ × 60″ cylinders and otherwise are similar to those for shaft *d*. Both have Zehnder's patent steam brake in addition to the ordinary hand-brake. The hoisting ropes used are $1\frac{3}{8}$-in. steel-wire rope, *d* shaft requiring 2,800 ft. and *c* shaft 2,500 ft. There are two ventilating fans *l*, one being kept for emergencies, and each run by

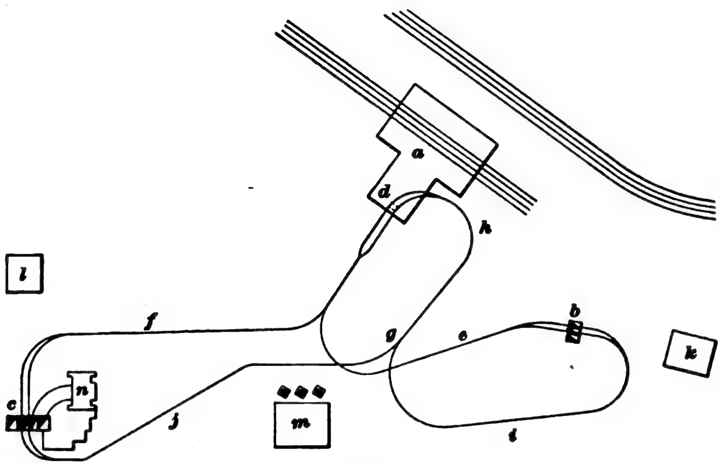


Fig. 9

a 20″ × 48″ direct-acting engine and provided with a pressure recorder. There are two steam plants. One plant, which is not shown on plan, but located about 100 ft. north of *j*, constitutes an independent plant, which can supply steam to the entire plant in case of accident to the other boilers at *k*. The whole steam plant consists of:

	Total H. P.
Eight 34-in. cylinder boilers, 30 ft. long, about 15 H. P. each	120
Two Pollock boilers	100
Four National water-tube boilers, 125 H. P. each	500
Two Stirling water-tube boilers, 125 H. P. each	240
Total	960

The breaker *a* is 116 ft. by 180 ft. in size and 145 ft. high. The breaker machinery is run by an 18″ × 36″ horizontal engine, and the cages in the breaker hoisting shaft are operated by a pair of 18″ × 30″ Vulcan engines, geared 4 to 1 to a cast-iron grooved drum 8 ft. in diameter by 20 in. long. The loaded mine cars are run by gravity over the tracks *f* or *e* from the head of each shaft to the foot of the breaker shaft, where each loaded car is run on one of the two hoisting cages and hoisted to the top of the breaker,

whence it is run by gravity to the dump chute. After a car has been dumped, it is carried by means of a transfer rope and a transfer track around the shaft and allowed to stand immediately back of the shaft on the same side that it was on when loaded. There is a sufficient fall between the transfer track and the breaker shaft to enable the empty car to "bump" the loaded car that comes up on the same side of the shaft. After the empty car leaves the cage at the foot of the breaker shaft, it runs by gravity to the foot of an empty car hoist *m* where it is hoisted to a point *n* that has sufficient elevation to carry the car over the tracks *g* or *h* back to either shaft to be again lowered into the mines.

Ques. 1433.—What does the Mine Law say as to the examination of machinery, shaft, ropes, etc.? *M.—B. C., Canada*

Ans.—Rule 31 of Section 82 makes it lawful for the persons employed in a mine to appoint one or two of their number to inspect the mine at their own cost, and provides that the person so appointed shall be allowed once or oftener in every shift, day, week, or month, to go to every part of the mine and to inspect the shafts, levels, planes, working places, return airways, ventilating apparatus, old workings, and machinery, and shall be afforded by the owner, agent, manager, and all persons in the mine every facility for making such inspection. The Rule makes it the duty of the person or persons making such inspection to enter a true report of the same in the book kept at the mine for that purpose, and to sign the same, and also provides that if the reports state the existence or apprehended existence of any danger, the owner, agent, or manager shall forthwith cause a true copy of such report to be sent to the inspector of the district.

Ques. 1434.—Where does the law require safety blocks to be used? *F.—Pa. (A)*

Ans.—The Anthracite Mine Law of Pennsylvania requires:

Safety blocks or some other device for the purpose of preventing cars from falling into a shaft or running away on a slope or plane, shall be placed at or near the head of every shaft, slope, or plane, and maintained in good working order.

CHAPTER XVI

METHODS OF WORKING COAL BEDS

REASONS FOR USING DIFFERENT METHODS

QUES. 1500.—Give reasons why different methods of mining are used, and why one method will not answer for all mines.

F_1.—Ala.

ANS.—The conditions existing in a coal field determine what method of mining is best adapted to that field; and as conditions vary greatly, it follows that one method of mining will not suit all cases. Different coal seams in the same region and the same seam in different regions are often widely different in respect to the character of the coal, roof, and floor, the thickness and inclination of the seam, depth of cover, and the gaseous condition of the strata. All these varying conditions affect the method of mining to be adopted. Every mine or seam should be carefully studied and that plan of mining selected that is best adapted to the existing conditions.

SINGLE, DOUBLE, AND TRIPLE ENTRY

QUES. 1501.—What is meant by the single-, double-, and three-, or triple-, entry system of operating and ventilating a coal mine?

M.—Ill.

ANS.—These three systems are so called from the number of parallel passageways or entries that are driven together in the coal, for the working of a single section of a mine or set of rooms or chambers. When a single entry or passageway is driven and rooms are turned from it, the system is known as the *single-entry system*. In this case, the ventilation of the rooms is accomplished by causing the air to return along the face of the rooms, passing out through a break-through, on to the main entry or reaching the upcast by a cross-cut or airway.

The *double-entry system* is a system in which the entries are driven in pairs. In this case, one entry of each pair serves as the haulage road and intake airway, while the other is used for the return of the air.

In the *three-entry*, or *triple-entry, system*, three parallel entries are driven

in the coal. In this case, the middle entry of the three is usually made the haulage road and the intake, the two outside entries being made the return airways for each side of the mine, respectively.

Ques. 1502.—Why is the single-entry system of operating almost certain to prove a failure? *M.—Ill.*

Ans.—Because it is difficult to maintain a good return air-course at the working face; and because a fall occurring at the face of any one of the rooms or on the entry, cuts off the ventilation of all the rooms inside of such fall, and there is little chance of restoring the ventilation quickly under these circumstances. Also, in case of accident, the escape of the men may be completely cut off.

Ques. 1503.—Describe, in detail, the developments and general arrangements you would expect to find at a large gaseous shaft mine, in full operation, the same being operated on modern scientific principles and according to law. *I.—Pa. (B)*

Ans.—This mine should be developed by driving the main headings on the triple-entry system, as shown in Fig. 1, the cross-entries being driven

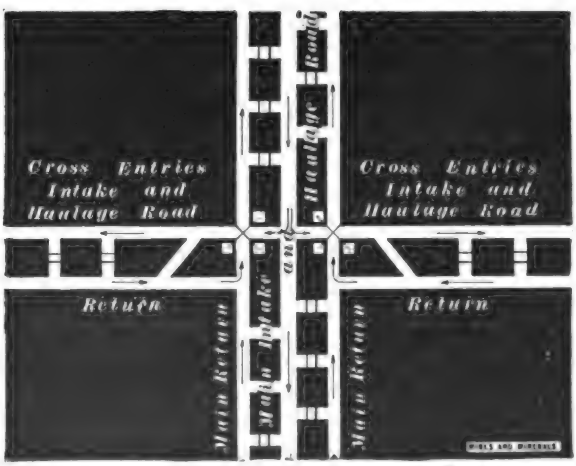


Fig. 1

in pairs, as shown. The middle entry of the main headings is made the intake and haulage road, while the two outer headings are made the return for each side of the mine, respectively. Overcasts should be constructed at the mouth of each pair of cross-entries, so as to provide a separate circulation for each district of the mine. The area of the airways should be such that the velocity of the current on the cross-entries will not exceed 450 ft. per min. The coal should be worked either on the panel system or in panel breasts. In the former, cross-headings are driven off the cross-

entries, say every 200 yd., dividing the coal into panels, each panel having its own circulation. The mining of coal is commenced in each panel as soon as the panel is formed. The method by panel breasts consists of driving rooms in sets, the number of rooms depending on the quantity of gas being given off at the working face. Each panel breast or set of rooms is ventilated by a separate current of air, taken from the gangway and conducted around the face of the breast, and returned directly to the return airway. Fig. 2 shows double entries and haulage upon the return, but if much gas is present the entries should be arranged as shown in Fig. 1. The most reliable form of safety lamp should be used exclusively in this mine, except on the main intake and haulage road. Lamp stations should be provided at the mouth of each pair of cross-entries. At the surface, the most improved ventilating apparatus should be in use, consisting of duplicate fans and engines. The fans should be run as exhaust fans, but should be capable of being converted into blow-down fans for use when the emergency requires. These duplicate fans and engines should be run alternately to relieve each other, one being held in reserve for use in case of breakdown. The fans should be set a sufficient distance from the opening to insure safety, and explosion doors should be provided over the shaft. There should be provided a good lamp house, where the safety lamps can be cleaned and kept in readiness for the men; there should also be a self-registering barometer and water gauge on the surface at the mouth of the shaft.

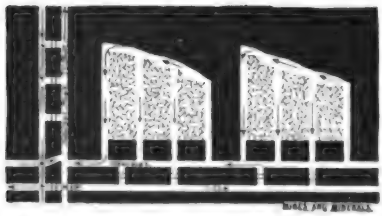


Fig. 2

ROOM AND PILLAR

Ques. 1504.—Show, clearly, by means of sketches, the two common methods of working a coal field, giving the conditions favorable to, or requiring the, application of each of these methods.

M.—Ill.

Ans.—The two general methods of working coal mines are the room-and-pillar system and the longwall system.

Room-and-Pillar System.—The main entries are first driven from the foot of the slope or shaft or the end of a drift, and cross-entries are turned off these generally at right angles. Single, double, or triple entries are employed according to conditions. In Fig. 3, the main and cross-entries are driven double. In flat seams, the rooms are turned off each of the cross-entries. In seams having an inclination greater than about 3°, the rooms are turned to the rise only. The length of the rooms is determined by the character of the roof, floor, and coal and varies from 60 to 100 yd. under favorable conditions. When the rooms are driven up, the pillars

are drawn back and the roof allowed to fall. This method is adapted to the working of flat seams having a thickness varying from 4 to 8 ft. or more, with fairly good roof and floor, and where the depth of cover does not exceed about 2,000 ft.

Longwall Method.—This method includes longwall advancing and

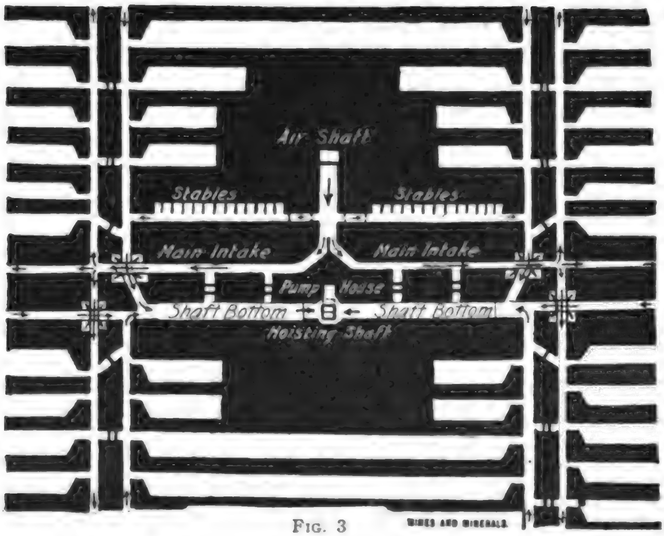


FIG. 3

longwall retreating. The first of these two methods is usually employed and is shown in Fig. 4. In this method, there are two modes of proceeding;

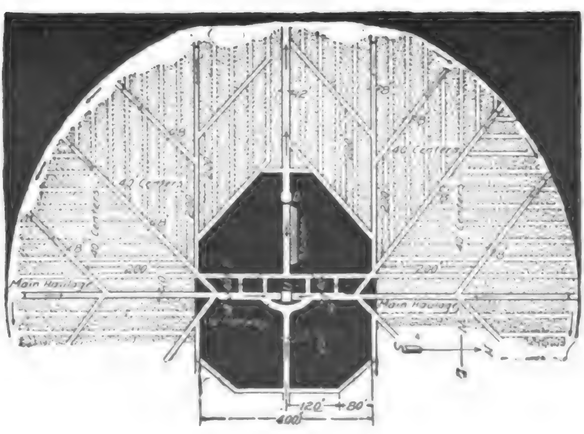


FIG. 4

the coal may be all taken out from the foot of the shaft, or, as is more usually the case, a sufficient shaft pillar is left to protect the shaft, and the

longwall face started just beyond this shaft pillar. The main roadways are maintained by building substantial pack walls on each side of the road. Diagonal roads are also built running at an angle of 45° with the main roads. These diagonal roads are spaced from 60 to 75 yd. apart, and working places or temporary roads are made, say from 12 to 15 yd. apart and running at an angle of 45° with the diagonal roads, or parallel to the main roads or cross-entries. The working face is advanced by undermining the coal along the entire circle of the face. When the mining is complete, the sprags are knocked out and the roof pressure is allowed to break the coal. In this method much depends on the uniformity of the work and the control of the roof pressure so as to throw the weight forwards on the face of the coal.

This method is adapted (1) to the working of thin seams, because it admits of a more complete removal of the coal; (2) to the working of coal at great depths because it provides for the gradual settlement of the roof, thereby avoiding the evils arising in other systems, from excessive roof pressure at great depths; (3) to the working of seams that require the handling of a large amount of dead material. Longwall is most successful where the roof is not too hard and yields gradually, allowing a uniform settlement.

QUES. 1505.—Describe and draw a sketch of pillar-and-stall working. *I.—Ill.*

ANS.—The pillar-and-stall method, Fig. 5, is a modification of the room-and-pillar method in which the rooms or stalls are driven up narrow with large pillars between them, which are drawn back when the stalls reach their limit, the roof being allowed to fall as the pillars are withdrawn. The method is adapted to a weak roof or soft bottom, or where the coal is weak.

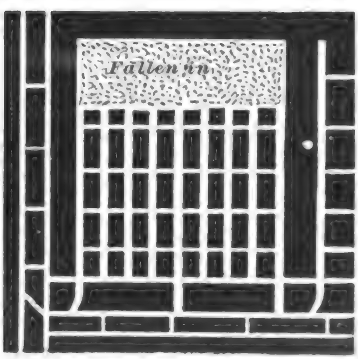


FIG. 5

QUES. 1506.—Under what conditions would you prefer the panel system of working to the ordinary room-and-pillar method? *M.—Ill.*

ANS.—The panel system is particularly adapted to the working of gaseous coal, as it affords separate ventilation for each panel or section of the mine. In the panel system, the ventilation of the mine is more readily controlled, and at any time more or less air can be introduced into a given panel or section as desired. An explosion taking place in one panel is not communicated as readily to the other panels or sections of the mine. The system is also employed to advantage under certain conditions of frail roof or soft bottom that are liable to cause a squeeze or creep.

QUES. 1507.—Explain the term barrier system of mining.

Ans.—The *barrier system* constitutes a mode of working a mine by which the workings in the same vein can be divided by barrier pillars into what is practically a series of mines all having their separate and individual ventilation, and only united by the main gangways.

LONGWALL MINING

Ques. 1508.—How would you develop a longwall mine, the property lines on the north, south, east, and west being 1 mile from the shaft, the depth of the shaft being 1,000 feet; all the coal to be brought out by means of one hoisting and the mine to be ventilated by one air shaft? *I.—Ill.*

Ans.—Fig. 4 illustrates the method of development of such a mine, *U* being the upcast and *D* the downcast shafts, respectively. The main haulage roads are laid out in a direct line, passing through the upcast shaft. A shaft pillar is left, as shown in the figure, to protect the two shafts, stables, and shaft bottom. Cross-roads are laid out from the bottom of the shaft and at each end of the shaft pillar, at right angles to the main haulage roads, thereby dividing the entire field into four quadrants and two side sections. Diagonal haulage roads are turned from these main roads every 200 ft., and working places, or roads, about 12 or 15 yd. apart lead from these diagonal roads to the face. These working places are cut off successively as the work progresses, by the next diagonal road, inby.

Ques. 1509.—What conditions should be observed in the development of a longwall mine? *F.—Ia.*

Ans.—The longwall mining is generally conducted as longwall advancing. The conditions necessary to be observed are: (1) To maintain a uniform line and a continuous regular advance of the working face, so as to properly regulate the roof pressure on the face of the coal. (2) To adopt a systematic method of timbering at the face, withdrawing the back timbers at regular intervals as required. (3) To build uniform pack walls, both as road and gob packs. (4) To turn off diagonal cross-roads and working places at regular intervals and at such distances apart as the character of the roof, floor, and coal may require. (5) To maintain the necessary height on all haulage roads by brushing the roof or lifting bottom. All these conditions vary according to the character of the seam and the overlying or underlying strata.

Ques. 1510.—What distance are rooms driven in longwall work generally before they are cut off? Explain the method of cutting off rooms, and state why the cross-entries are not driven at right angles with the main entry. *F.—Ia.*

Ans.—The distance of driving rooms in longwall work depends on the length of time the temporary roads can be kept open, which varies

according to the character of the roof and floor, depth of seam below the surface, proportion and stability of packs, and the quantity of water that finds its way into the workings. Under average conditions of mining, this distance may vary from 60 to 100 yd.

The rooms, as they reach this distance, are cut off in succession by a new diagonal started from the main road at an angle of 45° with the latter. The true cross-entries are driven at right angles to the main entries, but the diagonal roads make it possible to reach all points of the face more directly than by means of the cross-entries driven at right angles to the main entry, and these diagonal roads greatly reduce the length of haul.

COMPARISON OF METHODS OF WORKING

QUES. 1511.—Give the comparative advantages and disadvantages of the longwall, and room-and-pillar methods of working a coal mine. *F.—Ia.*

ANS.—As compared with the room-and-pillar method of working, the longwall advancing method possesses the following advantages: (1) All the coal is removed in the first working. (2) The settlement of the surface is gradual and uniform. (3) There is no expense for narrow work. (4) The mine is more easily and efficiently ventilated. (5) There is a minimum liability to falls of roof and gob fires. (6) A larger percentage of lump coal is obtainable. (7) The risk of squeeze or creep is avoided. (8) The cost of haulage and timbering is reduced to a minimum. (9) Ample room is afforded for the storage of waste instead of hoisting the same to the surface. The conditions under which the room-and-pillar system possesses any advantage over the longwall system is in the working of a gaseous seam of coal where the room-and-pillar system affords opportunity for isolating the different districts of the mine, either as separate panels or separate circulations. This system is also used in shallow seams where the roof pressure is not great; or where the roof is strong and unyielding and not adapted to the longwall method, or there is not sufficient refuse for building packs, and on steep pitches. The disadvantages of the room-and-pillar system as compared with longwall are numerous and may be stated as follows: increased cost of haulage, timbering and dead work, greater liability to falls of roof, cost of haulage, gob fires, and surface damages; the production of an increased percentage of screenings.

QUES. 1512.—In a field of 640 acres of coal, how would you satisfy yourself as to the best plan of working to adopt: the room-and-pillar, the longwall, or panel system? *M.—Ill.*

ANS.—The depth of the seam and the character and inclination of the strata are made known by the drill holes or prospect shafts previously sunk to the coal. The data furnished by these records will, perhaps, suggest the method of mining to be adopted; but this will be determined more definitely after the shaft has been sunk and the work of driving the main

entries begun. The longwall method is adapted to the mining of deep-lying seams of coal, owing to the enormous roof pressure; or thin seams lying at a moderate depth when the complete removal of the coal is important. Successful longwall mining, however, requires a yielding roof that will settle uniformly on the waste or gob packs, and the conditions are not always such that this method can be employed. The room-and-pillar method is used under a fairly good roof at moderate depths, say less than 2,000 ft. below the surface. With a frail roof, the pillar-and-stall method is often used, or the panel system; the latter being employed with advantage in the mining of gaseous seams.

INCLINED SEAMS

QUES. 1513.—Describe some of the methods used in working inclined seams. *F_1.—Ala.*

ANS.—In inclined seams, the main slope opening is usually driven on the full dip of the seam, and water-level entries driven to the right and

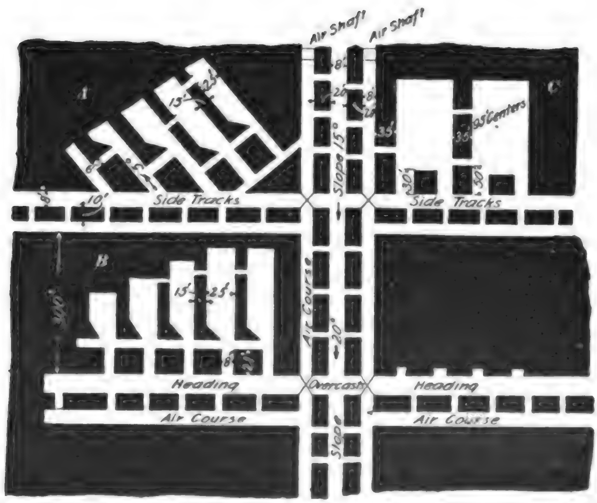


FIG. 6

left from the main slope, as shown in Fig. 6. Rooms are then turned to the rise of these levels and driven on the full pitch of the seam for inclinations up to 5°, or on an angle across the pitch, for inclinations of 5° to 10°. For inclinations varying from 10° to 20°, the coal is often lowered from the face to the gangway by some form of gravity incline, or the buggy system is adopted. When the inclination of the seam exceeds 20°, chutes are employed to convey the coal from the breast to the gangway level. The breasts are usually driven 8 yd. wide, with pillars varying from 10 ft. to 20 ft. thick between them; break-throughs are made in these pillars every 50 ft. for ventilation.

QUES. 1514.—What would cause you to turn off rooms at 45° instead of at right angles to the main heading? *F.—Pa. (B)*

ANS.—When the inclination of the seam is such that it becomes necessary to drive the rooms across the pitch in order to lessen the grade of the roads in the rooms and allow the car to be taken to the working face, or when the conditions are such that the coal breaks better by driving the breasts at an angle with the entry.

NARROW WORK

QUES. 1515.—What are the advantages, if any, of narrow entry work in a field where the coal is over 5 feet in thickness and overlaid by a good roof of tough slate that does not very often break? *M.—Ill.*

ANS.—In narrow work, the entries can be driven faster, as there is less material to excavate and handle; narrow openings will also require a less width of pillar and reduce the time and cost of driving break-throughs or cross-cuts. In thick seams, wide entries will require a large quantity of air being kept in circulation in order to produce a sufficient velocity to properly ventilate the roadways. The velocity should not be less than is necessary to produce thorough ventilation, and should not be less than the amount required by law, if this is fixed by law. In the Anthracite Law of Pennsylvania, the maximum velocity is stated as 450 ft. per min.

QUES. 1516.—What advantages are derived from driving narrow places in pairs? Make a sketch showing gangway, airway, and connecting cross-cut, together with two chambers, such as are worked in any mine in which you have been employed. *F.—Pa. (A)*

ANS.—Places so driven are easily ventilated by driving cross-cuts between them. The ventilation so established is more permanent and reliable than when bratticing is necessary to conduct the air to the face. Fig. 2 will illustrate the second part of this question.

ENTRIES

QUES. 1517.—If you were driving an entry in a 4-foot seam and you wanted the finished entry to be 8 feet wide and 5½ feet high above the rail, what width would you drive this entry to have room to gob your rock? *F_1.—Ala.*

ANS.—Assuming the total height of the entry to be 6 ft. in order to give 5½ ft. in the clear above the rail the roof must be brushed, that is to

say, 2 ft. of roof slate must be taken down for a width of 8 ft., and this slate is to be built up at the side of the entry where the 4 ft. of coal has been removed, as shown in Fig. 7. The area of slate to be removed is then $2 \times 8 = 16$ sq. ft., and the entry must be wide enough to give an equal stowage area at the side of the entry, or, since the coal is 4 ft. thick, $16 \div 4 = 4$ ft. extra width. The entry must therefore be driven $8 + 4 = 12$ ft. wide.

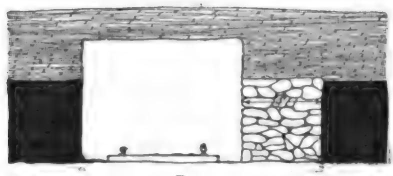


FIG. 7

QUES. 1518.—In a certain mine, the coal seam is 3 feet thick and overlaid with a strong roof; the bottom is fireclay and heaves badly. Eighteen inches more of height is needed on the haulage roads; state how you would secure this extra height. *F.—Ind.*

ANS.—This seam will probably be mined on the longwall system. Unless the roof is very hard, the 18 in. of extra height on the roadways, should be taken from the roof strata. The roadways as first laid out should be 12 or 14 ft. wide and the main road packs kept back a distance from the track, on each side. As settlement takes place, the height of the roadways is maintained by brushing the roof over the track, and the material taken down is built up on each side of the road. The packs on both sides of the road should be made wide, and care should be taken to induce a fall of roof as quickly as possible behind the working face, in the gob, in order to relieve the road packs and avoid the heaving of the bottom as much as possible. A good drain should be maintained on each side of the road close to the track, in order to keep the bottom dry and hard.

QUES. 1519.—How would you provide for the greatest degree of safety and economy in securing the entry roof, where there is from 2½ to 3 feet of heavy slate, full of slips, with a strong rock above the slate? *M.—Ill.*

ANS.—The greatest degree of safety will be secured by taking down this heavy slate, full of slips, and loading it out, or storing it in abandoned rooms. But as this will necessitate the handling of from eight to ten cars of slate every day in each entry, from a point of economy it will be impracticable. Another method combining a certain amount of security to the men, and a large amount of economy, will be to drive the entry narrow, taking out the coal only, and posting the roof well toward the face. Let a second working follow this, about 20 yd. behind the first, taking off a skip of coal from the outer rib of each entry of the pair, so as to make the entries each 12 instead of 8 ft. wide. As this coal is taken out along the rib, let the roof slate be taken down at the same time, and built along the rib in place of the coal removed. Great care must be exercised in taking down the roof slate, and in the skipping of the rib coal, as it is dangerous work, at the best. A row of props should be set by the men working at the face, along each rib of the entry, at least 4 ft. apart. These props can be used over and over again.

COST OF ENTRY WORK

QUES. 1520.—A pair of headings is driven 560 yards at $1.85 per yard; cross-cuts are driven every 20 yards, and are 8 yards long, at 40 cents per yard; the drain in each heading is 15 cents per foot, what is the total cost of driving such a pair of headings? *F.—Pa. (B)*

ANS.—

Driving two entries,	2(560×$1.85)	$2,072.00
Cross-cuts,	$\frac{560}{20}\times 8\times .40$	89.60
Two drains,	2(560×3×.15)	504.00
Total cost,		$2,665.60

QUES. 1521.—An entry is driven 600 yards; the cost per yard is $1.50; the drain alongside it costs 10 cents per foot; the ties in the road cost 9 cents each, and are placed 2 feet between centers; the T iron for road weighs 20 pounds per yard, and cost $30 per ton; the spikes are worth 2 cents each; what is the total cost of driving this entry, as stated? *F.—Pa. (B)*

ANS.—

Driving entry,	600×$1.50	$900
Drain,	600×3×.10	180
Ties,	$600\times\frac{3}{2}\times .09$	81
Rails,	$600\times 2\times\frac{20}{2{,}000}\times 30$	360
Spikes,	$600\times\frac{3}{2}\times 4\times .02$	72
Total,		$1,593

QUES. 1522.—What will be the cost of constructing a roadway 3,000 feet in length, laid with 20-pound steel rails costing $33.50 per ton; ties, 12½ cents each, spaced 2 feet between centers; spikes, $4 per 100 pounds, 10 spikes per pound; splice bars, 23 cents per pair; length of rail 30 feet; with a drain alongside to cost 33 cents per lineal foot? *F.—Pa. (B)*

ANS.—This roadway 3,000 ft. long will require:

Steel rails,	$\frac{3{,}000\times 2}{3}\times\frac{20}{2{,}000}$	= 20 T.	@ $33.50	$670.00
Ties,	$\frac{3{,}000}{2}$	= 1,500	12½ ct.	187.50
Spikes,	$\frac{1{,}500\times 4}{10\times 100}$	= 6 cwt.	$4.00	24.00
Splice bars,	$2\times\left(\frac{3{,}000}{30}-1\right)$	= 198 pr.	23 ct.	45.54
Drain,		3,000 ft.	33 ct.	990.00
		Total,		$1,917.04

QUES. 1523.—A main entry is driven 4,000 feet; it is 12 feet wide and 4 feet 6 inches high. We wish to lift bottom in this entry so as to make it 5 feet 6 inches high, and to put in a double-track haulage system. The contract for taking up bottom is 9 cents per inch of thickness, per running yard; steel rail, 16 pounds per yard, $38 per ton; ties, 6 cents at the bottom of shaft; spikes, $2\frac{1}{2}$ in. × $\frac{5}{16}$ in., at $3.75 per hundredweight; road man, $2.56 per day; helpers, $2.36 per day. Find the cost of the entire work.

M.—Ill.

ANS.—Following is an estimate of the cost of the work and the material per yard of entry:

		PER YARD
Lifting 12 in. of bottom,	$12 \times .09 =$	$1.08
Four 16-lb. rails (double track),	$\frac{16 \times 4 \times 38}{2{,}000} = \$1.216$, say	1.22
Ties (2 ft. apart), double track,	$2\left(\frac{3 \times .06}{2}\right) = \$\ .18$, say	.20
Spikes (200-lb. keg = 2,200 spikes),	$\frac{3.75 \times 8}{1{,}100} \times \frac{3}{2} = \$\ .04\frac{1}{11}$, say	.05
Laying and surfacing track (two men, 20 yd. per da.),	$\frac{2.56 + 2.36}{20} = \$.246$, say	.25
Total,		$2.80

It is customary, in estimating, to add about one-tenth for contingencies, making the total cost of laying the double track in this entry, say $3 per yd., or $1 per running ft. of entry; the total cost for the work will then be $4,000.

COST OF MINING

QUES. 1524.—What, in your opinion, are the things most neglected in the operation of a mine, whereby the cost of the coal is increased?

F_2.—Ala.

ANS.—The adoption of a suitable method of working; a sufficient size for all shafts, roadways, air-courses, and entry, and room pillars; the adoption of a proper system of haulage; proper hoisting and loading facilities, by which delays are avoided; a proper system of timbering in the airways and at the face; and a proper system of ventilation.

QUES. 1525.—What are the principal sources of expense connected with mining different coal seams?

F.—Ind.

ANS.—Some of the principal sources of expense in mining coal are as follows: the necessary dead work, such as entry driving, room turning,

driving cross-cuts or break-throughs, lifting bottom or brushing (ripping) roof to obtain the necessary headroom on roadways, and cleaning up falls of roof; the drainage, ventilation, and timbering of the mine; the movement of coal from the face to the tipple and loading, including maintenance of roads and cost of repairs of rolling stock, management, office expenses, company men, mine supplies, royalties on coal, marketing the coal, strikes and other delays, interest on investment, insurance, etc.

MINING IN CONNECTION WITH FAULTS

QUES. 1526.—By referring to Fig. 8, you will notice we have between the second and third east entries a rock roll, or horseback. The roll affects the coal seam and roof for about 12 feet across, and rooms when driven up to it must be renecked or driven through narrow. The price paid for such narrow work is 80 cents per foot. Explain how you would work this section, securing all the seam, yet piercing the roll as few times as possible. *F.—Ind.*

ANS.—The cost of holing through this fault will be $12 \times .80 = \$9.60$ each time that the fault is crossed. This expense should be avoided by

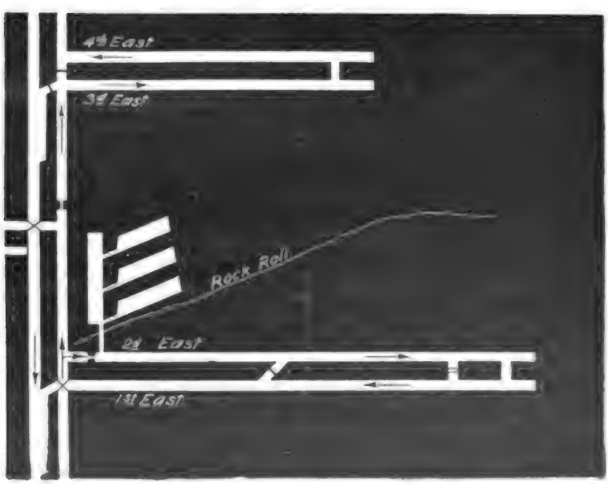


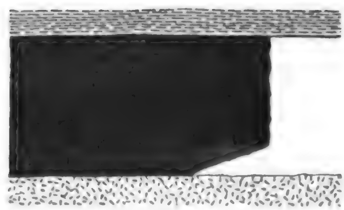
FIG. 8

cutting through the fault in No. 1 room only. This room may be driven, after crossing the fault, as a wide place (14 ft. wide), or if the roof is good the room may be widened out to the usual width after crossing the fault. The room should be turned off of the entry so as to allow of being widened outby instead of inby as is customary, and the road should be carried along

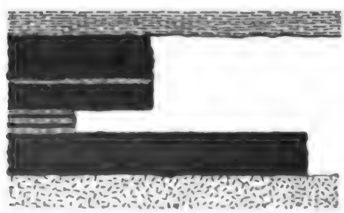
the straight rib. After crossing the fault, other rooms should be turned off this one, on the inby or straight rib. These rooms may be driven on an angle so as to skirt the fault; or they may be driven square with the first room, in which case the fault will cut off each room in turn. Another plan would be to cross the fault as before and drive a 14-ft. place skirting the roll and turn rooms off this place to correspond to the rooms on the entry; these rooms may be turned wide. As early as possible the rooms from both entries should be driven up to the roll and the trouble thus avoided.

QUES. 1527.—What changes are met with in coal, roof, and bottom, when approaching faults, and what dangers may be expected therefrom? *F.—Pa. (B)*

ANS.—The natural strata have often been much disturbed by the faulting and may present a broken and irregular condition that renders the roof treacherous and the work of mining dangerous, owing to the presence of unexpected slips and joints in the strata. A fault is often accompanied with a decided change in respect to water and gas; these sometimes disappear altogether when a fault is reached, while in other cases the quantity of water or gas is greatly increased beyond the fault. Gas and water frequently follow the line of a fault for a long distance, so that the quantity of water or gas given off at a fault is usually increased.



(a)



(b)

FIG. 9

WORK AT THE FACE

QUES. 1528.—With what methods of working coal at the face are you familiar? Draw a sketch illustrating your explanation. *F_1.—Ala.*

ANS.—Fig. 9 shows two methods of undercutting the coal. The undercut, holing, or mining may be made either in the underclay or in the lower layers of the coal itself as shown in (*a*); or in a clay parting or soft stratum of coal near the middle of the seam, as shown in (*b*). In the latter case, the upper bench of the coal is broken down first, by blasting or by wedges, and after its removal the lower bench is lifted by wedges or by a light lifting shot. In a thick seam of coal, the upper bench of coal is often mined a few yards in advance of the lower bench in the same manner as just described. Sometimes the coal is blasted from the solid without undercutting, the holes being made of a less depth in this case, and inclined at a considerable angle to the face to give the powder sufficient opportunity to perform its work. At other times, a vertical side cut, or shear, is made

from the top to the bottom of the seam to afford the powder an opportunity to work. Sometimes the coal is both sheared and undercut before blasting, Fig. 10. For a seam of coal less than 6 ft. in thickness, the depth of the undercut or of the shear is made about equal to the thickness of the seam.

FIG. 10

MACHINE MINING

QUES. 1529.—How would you develop a new mine to obtain the best results from machine mining? *F.—Pa.* (*B*)

ANS.—Assuming that the seam is flat and has a good roof and floor, the best results are obtained in machine mining when the rooms can be arranged in groups or panels so as to present one continuous breast. From four to ten or twelve rooms may thus often be arranged to be mined as a single breast called a *panel breast*, and less time is then lost in moving the machine from one breast to another. As much room as possible should be provided at the working face to allow of the easy movement of the machine along the face. Where the conditions of the roof or floor are such as to necessitate a cramped working of the machine at the face, much loss of time results. In the opening of a new mine, particular attention should be given to the direction in which the breasts are driven with respect to the cleats of the coal, in order to obtain the best results in regard to the breaking of the coal.

QUES. 1530.—What are the dangers connected with the operation of the different mining machines? What kind of machine do you prefer, and why? *F.—Pa.* (*B*)

ANS.—The dangers arising from the operation of any mining machine are principally those due to ignorance on the part of the operator as to the proper handling of the machine. An operator may receive a shock, accidentally or otherwise, in the operation of an electrical mining machine. In the operation of the pick machine, or "puncher," injury to the operator may occur by his inability to hold and control the machine when the blow is struck. A careless operator may be caught in the gearing of a chain machine, but as this machine is slow running such an accident is of rare occurrence and avoidable with proper care.

The preference for one or another of the different types of mining machines will depend largely on the conditions under which the machine must work. The two types most largely employed in American mines

are the pick and the chain-cutter machines. The longwall mining machine is coming into more general use in flat, regular seams underlaid with a soft mining dirt, or where the mining is performed in the coal itself. The successful operation of these machines requires, however, a greater continuous length of breast. Both the pick and chain-cutter machines are employed on inclinations up to 10° or 12°. On steeper inclinations, the pick machine is preferable, chiefly on account of the greater ease with which it may be moved from place to place. Pick machines require less room at the working face than any other type. These machines are also to be preferred where the coal is irregular or very hard, or contains sulphur balls.

QUES. 1531.—In mines having extremely tender roof, state what precautions you would adopt in introducing the various types of mining machines, to insure the safety of the employes and economy of operation. *F.—Pa. (B(*

ANS.—The ordinary chain-cutter machine will require a clear width of from 12 to 14 ft. between the timbers and face, which will not be possible to maintain under an extremely tender roof. The longwall machine requires less room between the timbers and the face than the chain-cutter; but whether either of these types of machines can be employed will depend on the character of the roof and the amount of timber required. The better plan to adopt will be to set sufficient timber to secure the face and use the pick machine in this case.

QUES. 1532.—What are the advantages and disadvantages in the use of the different kinds of mining machines, keeping in view health, safety, and economy? Answer fully.

ANS.—Undercutting machines are of two general types; the pick machine, in which a blow is delivered by a piston operated by compressed air similar to a rock drill, the miner grasping the machine with both hands and directing the blow; and the chain machine in which the undercut is made by a series of teeth set in an endless chain. The relative advantages and disadvantages of these two types of machine depend on the nature of the floor and roof at the working face, the amount of timbering required, the character of the coal, the presence of sulphur or boulders, and the inclination of the seam. Where the floor is regular and level, the chain machine can be used to good advantage and will generally undercut more rapidly and to a greater depth than a pick machine. It is, however, a heavy, cumbersome machine requiring more room at the face than a pick machine, and more time to transfer it from one working face to another. A pick machine can be much more readily handled where it is necessary to set props near the face and is much more under the control of the operator, and therefore better adapted where the floor is irregular or where the coal contains pyrites or boulders, that it is necessary to avoid in cutting. In the use of the pick machine, the miner is subject to a considerable jar by the force of each blow, but an experienced miner is not inconvenienced by this. The chain machine produces finer cuttings and requires a coal fairly free from pyrites for its

successful operation. Both types of machine are used in seams pitching as high as 10° or 15°, but much better results are obtained with the chain machine when the seam is nearly level, and it is not generally used when the pitch exceeds 12°. A chain machine cannot be used in coal that is so weak as to fall on the cutter and wedge it, after being properly spragged, as the work proceeds and it can seldom be used in drawing pillars, while a pick machine can often be thus used.

QUES. 1533.—(*a*) Under what conditions would you consider the use of mining machines inadvisable? (*b*) What conditions call for the use of punching machines for mining? (*c*) What condition would make the use of chain machines most desirable?

F.—Ind.

ANS.—(*a*) A very low seam, or a seam pitching above 13° or 18°; one with a bad roof requiring timber set close to the face; or one where much sulphur, many boulders, or other hard material is found in the mining bench.

(*b*) When the machine must be moved frequently from place to place; when the roof requires much timber; when the pitch of the seam makes handling of the machine difficult; when there are boulders or sulphur balls in the seam or in the mining dirt.

(*c*) When it is important to reduce the cutting in the coal to a minimum; when there is clean coal, a level floor, plenty of room between the timbers and the face, and a good length of face to be cut at one setting.

ANTHRACITE MINING METHODS

QUES. 1534.—Describe all the methods used in mining anthracite with which you are familiar, and state the varying conditions that make one preferable to another. *I.—Pa. (A)*

ANS.—The methods usually employed in the mining of anthracite are the room-and-pillar, or the pillar-and-chamber method, the pillar-and-stall method, and the panel system of mining. In some localities, where the cover is light, the method by stripping is employed. The longwall system of mining has not been successfully employed in anthracite workings, except to a very limited extent. These several systems of working coal, except the method by stripping, are fully described in answer to Ques. 1504. Certain modifications of the pillar-and-chamber method are required in seams of steep inclination, a chute for the coal being usually located in the center of the breast, with manways on either side. Where the inclination is very great the breasts are worked by building a temporary platform, or scaffold, at the face, or by the miners standing on the loose coal, in the chute. In this case, the chute is kept full, the loading out being done only as required. This system is called "working on battery." In stripping coal seams, the overlying strata are removed and the coal quarried out. This method is only adapted to seams lying close to the surface. The

pillar-and-stall method is adapted to seams having a weak roof or soft floor or both. The panel system is adapted to gaseous seams and to seams having bad roof liable to squeezes. The room-and-pillar method is adapted to seams having good roof and floor.

QUES. 1535.—What is the maximum pitch up which you would work breasts with roads, and what methods would you adopt in steeper pitches? Give a full description. *F.—Pa. (A)*

ANS.—When the pitch of the seam is from 5° to 10°, the car may generally be taken to the face and loaded, by driving the rooms across the pitch or at an angle with the level or gangway; this reduces the grade of the track in the rooms. When the inclination of the seam is greater, buggies are sometimes used, the track being built on the refuse of the seam and raised at its lower end where a dump is arranged by which the coal is

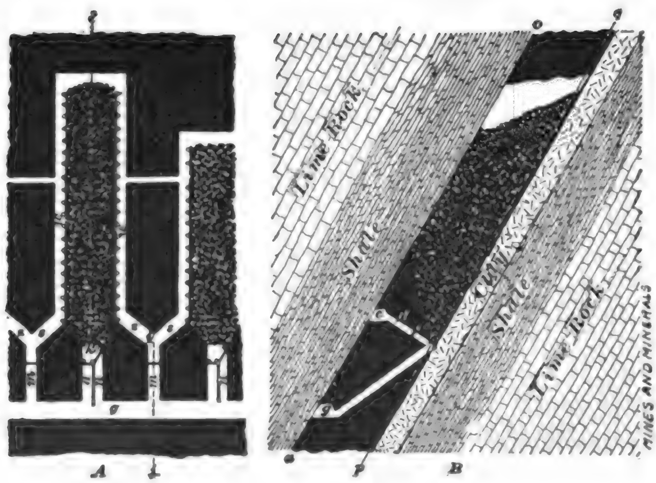


FIG. 11

dumped from the buggy into the mine car ready to receive it. Where the coal is soft, this method cannot be used. It is employed in thick seams, on pitches not exceeding 15° or 18°. Seams pitching more than 15° are usually worked by chutes. When the pitch is less than 30°, sheet iron is generally laid in the chute as a floor, to enable the coal to slide more easily; but on inclinations of less than 20°, it is even then necessary to push the coal down the chute, as it does not slide readily. On pitches steeper than 30°, sheet iron is not necessary, as the coal will slide without it. The arrangement and general method of driving the chutes is fully described in answer to Ques. 1536.

QUES. 1536.—What method would you adopt in working a seam 15 feet thick, pitching 65°, under an abandoned lift, to which access is not possible? *F.—Pa. (A)*

ANS.—The abandoned lift being inaccessible, its condition cannot be ascertained, and every precaution must be taken to avoid the dangers of driving the chambers too far and breaking through into the lift above. The method to be adopted is the room-and-pillar method illustrated in Fig. 11. The gangway being driven at the roof of the seam narrow chutes are opened out and driven across the seam to the floor at such an angle that the coal will run properly. At this point it is widened out to form the breast. A manway chute *m* is driven up likewise, in the center of each pillar between the loading chutes and where it intersects the floor of the seam it is branched to the right and left and driven to intersect the breasts on each side. Jugular manways *w*, built as shown in Fig. 12, are formed on the sides of each breast, the center of the breast being filled with loosened coal. In this manner, the breasts are driven up a safe distance, prospect holes being driven in the face of each chamber to ascertain the thickness of the pillar dividing the head of the chute from the lift above. A sufficient thickness of pillar must be left here to insure against accident, the thickness depending on the character of the roof, floor, and coal, and the supposed conditions of the abandoned workings. The question of drawing back the pillars will depend on the condition of the seam, as just mentioned, and is accomplished by cross-cutting and dividing the pillar in the usual manner.

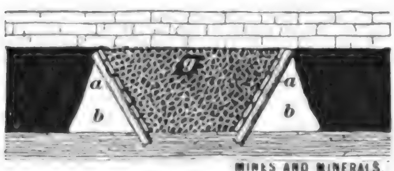


FIG. 12

QUES. 1537.—State what you consider the best method of working a seam 25 feet in thickness, with a bad slate top, and lying at an angle of 22°. *F.—Pa. (A)*

ANS.—Drive breasts, square up the pitch, about 6 yd. wide, and leave pillars of 12 yd. between the breasts. Carry a 5-ft. manway up each side of the breast, leaving the gob in the center of the breast. On a pitch of 22° the coal will run much more freely than the slate and other refuse in the seam, and as the coal is allowed to run down the manways (or probably pushed), the slate and other refuse can be picked out and thrown into the gob. The planks or slabs on the gob side of the props protecting the manways will be only one board high between the upper props, two boards high below, and so on, so that most of the refuse will only have to be lifted over a low partition. In many coal seams, there is a bench of hard coal near the top. In driving up the breast, select the best and smoothest parting, from 5 ft. to 10 ft. below the top slate for the roof of the breast, thus making it probably 15 ft. high, possibly not more than 10 ft., and as the ribs are never cut square up and down, the breast will be in the form of an arch and the manway props will not be more than 6 ft. or 8 ft., possibly 10 ft. long.

When the breast has been driven to its limit, start at once at the face and cut out the wings or arched portion of the sides, square up to the parting forming the roof of the breast, and the chances are that the top coal will

fall. If it does not fall when the wings have been squared up for one or two lengths of manway plank (say 6 ft. to 12 ft.), blast it down. Repeat this in short sections all the way down the breast.

The manways being narrow and the gob twice as wide, the manways will now have a tendency to block with the fallen coal and slate, especially if the top slate falls at once. The coal must be picked out and passed down the manway and the refuse thrown back into the gob. If the top slate does not fall at once, a lot of handling of slate will be saved, for when it does fall it will not run very far on this pitch and will "tail out" to nothing when it strikes the gob. In this method, there is no propping of the top slate, nor any effort made to hold it up.

The *stump pillar*, or the pillar between the gangway and the first cross-heading, should be at least 10 yd. thick, and the top coal should only be taken down to, say, 3 yd. or 4 yd. above this heading. Work about ten breasts in this manner, then omit working two breasts, leaving a solid pillar; then work another section of ten breasts, omitting to work the next two, and so on. This leaves a solid pillar of coal 48 yd. wide between each section to stop any squeeze that may occur in any one section of 10 breasts, 168 yd. wide, and these pillars can be taken out later on, the same as working new breasts.

After the second section of ten breasts has been worked as above, start at the outer end of the first section and drive a chute from 4 to 5 yd. wide, depending on the nature of the coal, in each of the 12-yd. pillars left between the breasts already worked; drive this chute up to the breast limit, and take down the top coal and as much of the small pillars on each side as can be got, all the way down to a few yards above the stump heading, in the same manner as the original breasts were worked. The stump heading must be preserved, and the reserve pillars between the sections of ten breasts, should be cross-cut at the faces of the adjoining breasts to keep up the circulation of the air.

Ques. 1538.—How would you work and timber the breasts in a seam of free coal 12 feet thick with a bad top, on a pitch of 18°, in order to procure the largest possible quantity of coal, and with due regard to the safety of the workmen, and what plan would you adopt for robbing the pillars? *F.—Pa. (A)*

Ans.—Breasts should be opened narrow and driven 40 to 50 ft. apart a distance of 8 or 10 yd. up the pitch. At this point, the pillars are cross-cut and the breasts widened out to a width of 5 or 6 yd. The work must be conducted carefully, timbering the coal so as to support a portion of the breast while the other portion is being mined or allowed to run. If a harder stratum of roof coal can be had in the top of the seam, this should be left up to support the roof, until the drawing of pillars is commenced. If the coal is very soft, great care will be required to support the coal at the face and keep the manway open. Timbers should be maintained for this purpose close to the face and the coal lagged if necessary. If the seam is gaseous, the running of the coal will set free large volumes of gas, which will often

render the working of the breasts extremely dangerous. In such case, safety lamps alone must be used and the breasts worked singly or in pairs, each breast or pair of breasts having a separate air-current, the intake air passing up the manway on one side of the breast and returning down the manway on the opposite side, and thence by a short monkey airway or cross-cut to the main return located above the gangway. This arrangement, in case of an accident in one breast, insures the unobstructed ventilation of the other breasts. The breasts should be driven in panels or groups of eight or ten, and reserve pillars left by omitting to drive one or two intervening breasts until later. Each group of breasts has its own circulation. When the breasts are driven to their limit, the work of drawing back the pillars is commenced. The face of the coal having been thoroughly timbered and secured against running, a chute is driven up the center of each pillar as far as the top of the breast and the pillar worked backwards, taking down the roof coal and as much of the pillar coal as possible.

Ques. 1539.—How would you proceed to open chutes in the Mammoth seam, on a pitch of 55°, where the coal is free? What distance from the gangway would you consider proper to drive the first cross-cut? *F.—Pa. (A)*

Ans.—The coal forming the upper rib of the gangway should be properly secured on each side of the chute by constructing a substantial timber frame in the gangway. The chute should be opened narrow, say 2 yd. wide, and driven from the gangway near the roof of the seam, across the seam on a proper loading angle, say 30°, so as to reduce the tendency of the coal to run. This chute should be driven for a distance of about 10 yd., or until the floor of the seam is reached, before the first cross-cut is made; the chute should be well timbered to secure the top and sides, lagging being used behind the timbers if necessary. As explained in Ques. 1536, a manway may be driven up the center of each pillar between breasts the same distance and then branched to meet the widened breast, instead of driving the first cross-cut connecting two breasts.

Ques. 1540.—It is proposed to open a colliery on the following workable seams: Buck Mountain, 10 feet thick; Skidmore, 8 feet thick; and Mammoth, 25 feet thick, pitching respectively 30°, 35°, and 38°. On which seam would you sink your slope; where would you place your fan; and what kind of a fan, in your opinion, would give the best results, forcing or exhaust fan? *F.—Pa. (A)*

Ans.—The choice of seam in which to drive the main slope will depend much on the character of the surface at the outcropping of these seams, as affecting the loading and shipment of the coal and the location of the necessary buildings, supply yards, etc. forming the plant. In general, the main haulage slope may be sunk in the thickest seam, which in this case is the Mammoth, lying above the other two seams mentioned. The fan may then be placed at the mouth of an airway driven in the middle of the

Skidmore seam. This fan should be an exhaust fan, and arranged to exhaust the air from the workings in both the Mammoth and Buck Mountain seams. The main haulage slope in the Mammoth seam is thus made an intake airway; a second intake may be arranged by driving a slope in the Buck Mountain seam, or this seam may be ventilated by a split taken from the main intake in the Mammoth seam through the cross-tunnel joining the seams.

Ques. 1541.—A slope is sunk on the Buck Mountain seam a distance of 350 feet on an angle of 40°; from the bottom of this slope, a tunnel is driven cutting the top and bottom splits of the Mammoth seam, the coal from the two latter splits being drawn through this tunnel. The gangways extend 4,000 feet on each side of the tunnel, a reservation pillar being left every 500 feet. Owing to the enormous expense in keeping these gangways open, the present method must be abandoned; can you suggest a plan to win this coal that will be profitable to the operator? *F.—Pa. (A)*

Ans.—The question does not state the length of the cross-tunnel or thickness of the rock strata separating these seams, but it is evident from the conditions that the gangways have reached or probably exceeded their limit as far as economy in handling the coal is concerned. If the conditions in the Buck Mountain seam are such as to permit of a greater length of gangway, and the distance between the seams is not too great, cross-tunnels can be driven from the Buck Mountain gangway to reach the two splits of the Mammoth seam at such intervals as are warranted by the relative expense of driving a new cross-tunnel and maintaining the gangway roads on the splits of the Mammoth seam. The relative expense will determine how often these cross-tunnels should be driven. The length of the Buck Mountain gangway will, in like manner, be limited or determined by the relative expense of maintaining this gangway as compared with the expense of moving the surface plant, or sinking and equipping a new slope road.

CHAPTER XVII

COAL PILLARS

SIZE OF PILLAR AND OPENING

Ques. 1600.—In mining coal by the room-and-pillar method, what should be the rule for determining the relative size of pillars and rooms? *I.—Ia.*

Ans.—The general conditions determining the size of room pillars are: depth of seam or thickness of cover, which determines the roof pressure; strength of roof and character of bottom, a hard roof or soft bottom requiring thicker pillars, while with a soft roof or hard bottom the pillars may be of less width; the character of the coal, a soft, frail coal requiring thicker pillars, while with a hard coal the width may be decreased. The thickness of the seam increases the size or width of pillar. The inclination of the seam also affects, to some extent, the thickness of the pillar, steep seams requiring thicker pillars than are necessary in seams of less inclination. The size of openings, or width of rooms or chambers, depends largely on the same conditions. Thickness of cover or depth of seam, which determines the roof pressure affects directly the width of the opening. The latter decreases as the depth increases. A weak roof or soft bottom decreases the width of the opening, while a strong roof and floor may permit of wider openings. The safe width of opening depends much on the character of the roof rock.

Ques. 1601.—What should be considered in determining the size of pillars in mines? *F.—Pa. (A)*

Ans.—The essential factors in calculating the size of pillars are the thickness and inclination of the seam, the depth of the cover, and the character of the coal and of the top and bottom rock and the width of the opening. It is impossible to give exact rules or formulas for determining the proper size of pillars. Each case, in practice, requires special consideration. In general, the thicker the seam, the greater its depth from the surface, and the greater its width of opening, the greater should be the thickness of the pillar. Some coal deteriorates rapidly when subjected to weight and to the disintegrating effect of the atmosphere, and pillars of such coal must be larger than when composed of a hard, compact coal. Permanent

pillars, or those that are to remain for a considerable length of time, must be larger than those that are to be promptly removed. Pillars about the bottom of a shaft or along main haulage roads, should be left large enough to provide for increasing developments, for when landings are enlarged or when mechanical haulage systems are introduced, the original pillars frequently have to be reduced in size by taking a skip off of them or by taking out chambers for engines and pumps. A hard roof that does not break requires an increased width of pillar. A frail coal also requires wider pillars. On the other hand, a soft, yielding roof that falls, or a strong coal, decreases the necessary width of pillars. The roof pressure per square foot exerted on the pillars is proportional to the depth of cover and the total width of opening and pillar, and inversely proportional to the width of the pillar. Or, calling the depth of cover d, the width of opening o, and the width of pillar w, the roof pressure per square foot exerted on the pillars is proportional to the expression,

$$d\left(\frac{w+o}{w}\right)$$

Ques. 1602.—What conditions would guide you in determining the width of headings and rooms? *F.—Pa. (B)*

Ans.—The width of headings and rooms depends on the depth of cover and the character of the roof and floor. The roof pressure is directly proportional to the depth of cover. A hard, self-supporting roof will permit of a greater width of opening, and this is likewise true of a firm, solid floor underlying the seam.

Ques. 1603.—What, in your judgment, should be the difference in the thickness of pillars left to support the overlying strata of a mine between that of a 10-foot seam and that of a 30-foot seam; and which should be the larger pillar, on a pitching seam or on a horizontal seam? *F.—Pa. (B)*

Ans.—There is no experimental data regarding bituminous coal upon which to base a definite answer to the first part of this question and the answer must depend on judgment and experience. An approximate answer may be given by assuming the pillar to resemble a column, in which the width of pillar should vary as the square root of the thickness of the seam. In this case, the ratio of the thickness of the seams being $\frac{30}{10} = 3$, the ratio of the width of pillars should be the $\sqrt{3} = 1.73$; that is, the pillars in the 30-ft. seam should be 1.73 times as wide as the pillars in the 10-ft. seam.

In inclined seams, the roof pressure or weight on the pillars varies with the cosine of the angle of inclination of the seam. Thus for an inclination of 30°, the weight on the pillar is .866 of the weight on the pillar for a flat seam under like conditions. There are other conditions, however, operating in inclined seams, that often require a greater rather than a less thickness of pillar in such seams. Among these conditions is the tendency of the roof

to slip downwards, which is very destructive to the pillars. Under these conditions, the width of the pillar can only be determined by practical experience in the locality.

Ques. 1604.—If the pillars in a vein of coal 8 feet thick are left 7 yards wide at a depth of 230 feet, how wide should pillars be left at a depth of 895 feet in a vein 20 feet in thickness, of the same quality of coal? *M.—B. C., Canada*

Ans.—There is no general rule or empirical formula covering this case, but a rule sometimes used is to make the width of pillars in mine workings proportional to the square root of the product of the depth of the seam times its thickness, giving, in this case,

$$x = 7\sqrt{\frac{895\times 20}{230\times 8}} = 21.83 \text{ yd.}$$

PILLARS

Ques. 1605.—In a shaft mine 300 feet deep, in a 4-foot seam of coal with rock top and bottom, what size of shaft, heading, and

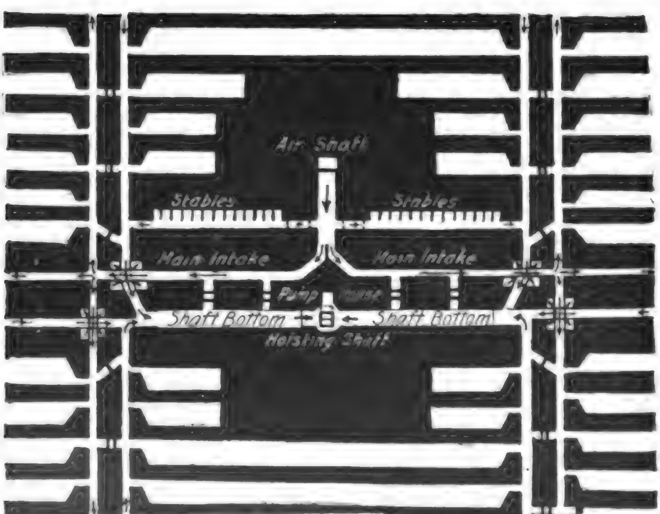


Fig. 1

room pillar would you use? What size airway would you drive? How would you arrange the shaft bottom to handle 2,000 tons of coal in 8 hours? *I.—Pa. (B)*

Ans.—The shaft pillar may be calculated by the formula

$$\text{radius of pillar} = 3\sqrt{D\times t} = 3\sqrt{300\times 4} = 104 \text{ ft.}$$

The main haulage roads in this mine should be driven 8 or 10 ft. wide to provide safe passing room for men or animals at the side of the track and with a pillar of 30 to 40 ft. along the roads. The butt headings will be 8 ft. wide and have a solid pillar 40 to 50 ft. wide between them. Driving the rooms 21 ft. wide, the width of the room pillars should be 12 to 20 ft.

To determine the size of airway required, it is necessary to approximate the number of men employed in the mine. Assuming an average of somewhat less than 3 T. of coal per miner per day, an output of 2,000 T. will require 700 miners, 30 drivers, 30 mules, and 20 company men, including timbermen, trackmen, cagers, runners, and trappers, making a total of 750 men and 30 mules in the mine. Assuming a non-gaseous mine, and allowing 100 cu. ft. of air per min. per man, and 500 cu. ft. per mule, the circulation required will be 90,000 cu. ft. of air per min., or 45,000 cu. ft. on each side of the shaft. Driving the airway 6 ft. high and 9 ft. wide will give a sectional area of 6 ft. $\times$ 9 ft. = 54 sq. ft., which will accommodate this circulation at a velocity of $45{,}000 \div 54 = 833$ ft. per min. in the main airways. The general arrangement of a shaft bottom, main, and cross-entries and stables that may be adopted in this case is shown in Fig. 1. The main shaft-bottom entry is driven 16 ft. wide, a distance of 60 yd. on each side of the shaft.

QUES. 1606.—What size of pillar would you leave at the bottom of a shaft 500 feet deep; the average covering is 525 feet, coal 8 feet thick, under the coal is 3 feet of fireclay, and under the clay, 2 feet 6 inches of limestone; above the coal is 2 feet of slate, above the slate, 12 feet of limestone, and above the limestone are soapstone, shale, clay, gravel, sand, and soil? What size of pillars would you leave between the main entry and return airway; what size of pillars between cross-entries; what size of pillars between rooms and return airway, and rooms and main entry? The shaft is in the center of a piece of land containing 1,280 acres, and all the coal must come up the shaft. *M.—Ill.*

ANS.—The diameter of the shaft pillar, in this case, may be calculated by the formula

$$D = 3\sqrt{d\,t} = 6\sqrt{500 \times 8} = 380 \text{ ft.}$$

The rule given by Hughes provides 1 yd. of thickness of pillar for each yard of depth, making the diameter of the pillar, in this case, 500 ft. The formula of Merivale makes one side of a square pillar, in this case,

$$3 \times 22\sqrt{\frac{500}{6 \times 50}} = 85+ \text{ ft.}$$

These two formulas represent the two extremes of the rules given by a large number of authorities, but the formula used, $D = 3\sqrt{d\,t}$, probably represents a fair average of the various authorities. The size of entry pillars may be determined from the size of room pillars, which depends on the relative sizes of pillar and opening, or the percentage of coal removed in the

first working. Under the conditions mentioned, the safe width of opening will depend largely on the strength of the 12 ft. of limestone overlying the 2 ft. of roof slate. Since the roof pressure per sq. ft. for a depth of cover d, is 160 d if the width of room pillar is w, and the width of opening o, the load thrown on these pillars by the removal of the coal in the rooms is, practically,

$$L = \frac{160\,d}{2{,}000}\,\frac{w+o}{w} \text{ tons per sq. ft.} \qquad (1)$$

The relative sizes of pillar and opening must be such that the pillars will safely support this load. The strength of mine pillars depends on the quality of the coal and may be considered to vary approximately as the square root of the ratio of the width of pillar to the thickness of the seam. The crushing strength of a pillar may therefore be represented by the formula

$$S = C\sqrt{\frac{w}{t}}$$

where C is a constant representing the crushing value of the coal in tons per square foot for a ratio $\frac{w}{t} = 1$. Experiments upon the crushing strength of anthracite, give a value for C of $C = 50$ to 70 T. per sq. ft. Similar, but much less extensive, experiments upon Illinois and Ohio bituminous coal give a value for C of $C = 30$ to 40 T. per sq. ft.; assuming, in this case, $C = 35$ and $o = 30$ ft., the strength of the pillar coal is

$$S = 35\sqrt{\frac{w}{t}} \qquad (2)$$

But, since the strength of the pillar must be equal to its load per square foot of area, $S = L$, in formulas **1** and **2**; and the value of w must be such as to satisfy the formula

$$35\sqrt{\frac{w}{t}} = \frac{160\,d}{2{,}000}\,\frac{w+o}{w} \qquad (3)$$

The value of w is found by trial; thus, suppose that one-half of the coal is taken out in the rooms, making $w = o = 30$; whence $\frac{w+o}{w} = \frac{30+30}{30}$, and, substituting values in formula **3**,

$$35\sqrt{\frac{w}{8}} = \frac{160 \times 525}{2{,}000} \times \frac{30+30}{30}$$

and,
$$w = 8\left(\frac{160 \times 525}{2{,}000} \times \frac{30+30}{30} \times \frac{1}{35}\right)^2 = 46+ \text{ ft.}$$

The true value of w then lies between 30 and 46. Again, try $w = 38$; whence $\frac{w+o}{w} = \frac{38+30}{38}$; and substituting values in formula **3**, and reducing, we have, finally,

$$w = 8\left(\frac{160 \times 525}{2{,}000} \times \frac{38+30}{38} \times \frac{1}{35}\right) = 36+ \text{ ft.}$$

The true value of w is therefore between 36 and 38, or say $w = 37$. The proper widths of opening and pillar, in this case, are $o = 30$, and $w = 37$, respectively. For main and cross-entry pillars, a good rule to adopt under

the given conditions (strong cap rock), is to make the width of main-entry pillars at least equal to that of the room pillars (36 ft.). The main-entry pillars are frequently made much wider than the room pillars and the practice of the Illinois Mining Board calls for a pillar 60 ft. wide under the given conditions. The width of cross-entry pillars may be the same as on the main entries, or where the cross-entries are maintained a shorter time than the main entries the pillars may be less than the main-entry pillars, and care should be taken not to draw the room pillars back too close to the entries, and the roof should be broken inside the mouth of each room when the pillars are drawn.

QUES. 1607.—In timbering a room, how far apart would you place timbers, under a fair roof? If the top is bad, how should they be placed? Also, how would you set a prop to carry the greatest possible weight? *I.—Ill.*

ANS.—A good rule for post timbering is to make the smaller diameter of the post, in inches, equal to its length, in feet; then multiplying the area, in square inches, for this diameter by one-half the average crushing strength (3,500 lb. per sq. in.) of the timber, the weight safely supported by such timber is found. Thus, using 6-ft. timber in a 6-ft. seam, and making the smaller diameter of the timber at least 6 in., the safe load for each post is

$$\frac{.7854 \times 6^2 \times 3{,}500}{2{,}000} = 49.4, \text{ say } 50 \text{ T.}$$

Under a fair roof, the height of the overarching loose material resting on the timbers may be assumed as one-half the width of the opening; hence, multiplying one-half the width of the opening by the weight of the strata per cubic foot gives the weight of material per square foot of roof supported by the timbers. Thus, for an opening 8 yd. wide (24 ft.), the roof pressure per square foot supported by the timbers under a fair roof may be taken as $\frac{24}{2} \times 160 = 1{,}920$ lb., say 1 T. In this case, since each post will safely support 50 T., each post will support $\frac{50}{1} = 50$ sq. ft. of roof, and the distance between the posts is therefore $\sqrt{50} = 7+$ ft. For a weak or frail roof, the height of the overarching material may be assumed as equal to the width of the opening, which will double the roof pressure per square foot, and reduce the area of roof that can be supported by each post one-half, giving for the distance between the posts in this case $\sqrt{25} = 5$ ft. Much will depend on the nature of the roof and floor strata; with a very soft roof, large caps will be required, and it may often be necessary to set the posts not more than 3 ft. apart, to prevent the roof breaking and falling between them.

QUES. 1608.—Under the usual existing conditions, what size breast pillars would you recommend in mining the Mammoth coal seam, 40 feet thick, on the fourth level, in the Mahanoy Valley? *I.—Pa. (A)*

ANS.—This question is to some extent an open one, calling for opinions as guided by experience in different workings of this seam. Under ordinarily good conditions, it has been found safe in driving an advance breast in this seam to make the width of the opening 30 ft., and to leave a 40-ft. pillar between the openings.

QUES. 1609.—In a bed of hard coal with a bad roof dipping at an angle of 60°, what size pillars would you recommend to be left on the third-lift gangway? *I.—Pa. (A)*

ANS.—The depth of the seam or thickness of the cover not being mentioned, we will assume that it does not exceed 200 ft. If the roof is frail and treacherous, the working faces should be driven up narrow and with wide pillars between them. The breasts may be driven, say, 6 to 10 yd. wide with pillars between them of widths varying from 10 to 20 yd., according to the conditions of floor and roof. In many cases, a skip would be taken off the pillar after the breast has been driven up full length. The gangway pillars we would not make less than 15 yd. in width. Great care will be required to guard against slipping of the roof.

BARRIER PILLARS

QUES. 1610.—An abandoned portion of a mine having a dip of 2 per cent. for a distance of 7,000 feet is filled with water; what thickness of barrier pillar must be left to protect the workmen in adjoining mines working to the rise in the direction of these abandoned workings? *I.—Pa. (B)*

ANS.—The Bituminous Mine Law of Pennsylvania requires that 1 ft. of pillar be left for $1\frac{1}{4}$ ft. of water head. Assuming the vertical head of water in this case to be $7{,}000 \times .02 = 140$ ft., the minimum thickness of barrier pillar required by law is $140 \div 1\frac{1}{4} = 112$ ft.

QUES. 1611.—What determines the size of a barrier pillar in the anthracite field? *I.—Pa. (A)*

ANS.—The following rule has been agreed upon by a number of the anthracite companies for calculating the size of barrier pillar: (Thickness of workings $\times$ 1 per cent. of depth below drainage level) + (thickness of workings $\times$ 5) = width of barrier pillars. All dimensions in feet.

QUES. 1612.—In approaching an abandoned mine full of water having a head of 300 feet, the pillars of which have been extensively robbed, how much of a barrier pillar would you consider it necessary to leave for the safety of your workings, so that you could rob your pillars back in a seam of free coal 8 feet thick on a pitch of 12°?
M.—B. C., Canada

Ans.—The Bituminous Mine Law of Pennsylvania specifies for a minimum thickness of barrier pillar, $1\frac{1}{4}$ ft. of thickness for each foot of head of water. Applying this rule in this case the thickness of pillar is $300 \times 1\frac{1}{4} = 375$ ft.

DRAWING PILLARS

Ques. 1613.—Explain the different systems of drawing pillars, and state if you consider it always best to have large rib pillars when the thickness of the overlying strata varies from 80 to 300 feet. *F.—Pa.* (*B*)

Ans.—The methods of drawing pillars may be divided into two classes namely: drawing at once by end lifts, as *A*, *B*, and *C*, Fig. 2, and drawing, in sectional divisions, as in *D* and *E*. In the first method, the drawing begins by cross-cutting the fast ends of the pillars to obtain a retreating face. At *A*, the coal is soft and the pillars are narrow, consequently no special rule is required for dividing the pillar at the face. At *B*, the pillars are wider and the end face is taken in two parts, as shown. At *C*, the pillars consist of moderately hard coal that can better be drawn in three parts or lifts. In the second method of drawing, as at *D* and *E*, the pillars are cut up into sections to be drawn by side or end slices, according to the nature of the coal, the inclination of the seam, the thickness of the cover, and the strength or weakness of the roof and floor. The systems of drawing that secure the highest percentage of pillar coal never allow the pillars during their removal to be squeezed or crushed. The best two general systems of drawing are the following: (*a*) All the pillars in a panel are taken out, together with end lifts or slices, in such a way as to keep the faces of all the pillars in line and perpendicular to the sides of the pillars. (*b*) In this system, the pillars are drawn by beginning with cross-cutting through the fast ends of the innermost pillars in a panel. Three or more pillars, according to circumstances, are drawn at once, and the centers of the faces of the pillars are made to lie in a straight line that makes an angle of 40°, more or less, with the sides of the pillars. It cannot be determined what the sizes of the pillars should be without first knowing the inclination and thickness of the seam, the hardness of the coal, the wet or dry condition of the seam, and the nature of the roof and floor; but where the depth varies so much, the widths should be those due to the maximum thickness of the cover.

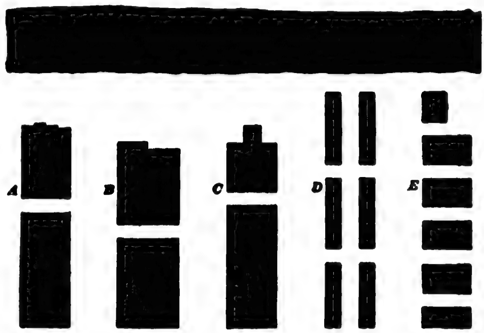


Fig. 2

QUES. 1614.—Explain what, in your opinion, is the best method of robbing pillars in a seam 8 feet high, under a cover varying from 20 to 100 feet. *F.—Pa.* (*A*)

ANS.—Robbing pillars, or drawing pillars, under the conditions named in the question will often be exceedingly difficult. Much depends on the nature of the cover. Two methods are in general use. (*a*) By flushing: in this method dams are constructed at the bottoms of the breasts, and culm is washed into the breasts through bore holes from the surface until the breasts are completely filled. After a time, the pillars are split by a narrow place driven up the center of the pillar, and the coal on each side is then drawn back. (*b*) By drawing back the entire pillar at once: in this method work is begun at the inby end of the pillar. Posts are first set securing the roof. Thick pillars are worked back in skips taken off the rib, on one or both sides of the pillar at once. Back timber is drawn regularly and the roof allowed to fall a sufficient distance behind the workmen.

QUES. 1615.—How would you proceed to rob a section of a mine where the gangway has been driven to the boundary line, with the view of obtaining the largest percentage of coal and guarding the lives and safety of the workmen? *F.—Pa.* (*A*)

ANS.—The work of robbing or drawing back the pillars in this case is commenced at the innermost chambers, and proceeds toward the outlet of the mine. In many instances, the best results are obtained by drawing back all the chamber pillars on a gangway at once. In any case, the pillar workings should be kept in a uniform line so as to avoid the undue weighting of any of the pillars that may chance to fall behind, which would cause the crushing of the coal and render work more hazardous owing to the difficulty of preventing dangerous falls of roof. A uniform line of pillar workings will also yield a larger percentage of lump coal. No standing timber should be left as the pillars are drawn back. Care must be exercised that the drawing of the pillars in one section of a mine does not throw undue weight on another section.

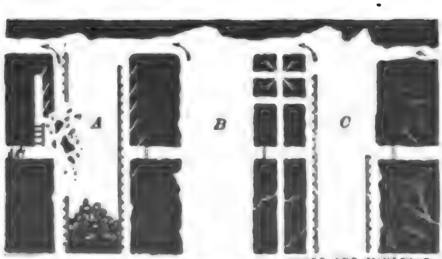


FIG. 3

QUES. 1616.—In a gangway, driven in a coal seam 10 feet thick, with a bad top and heaving bottom, forty breasts have been worked up a distance of 60 yards, at an angle of 60°, and are standing full of coal; the breasts and pillars are 8 yards wide. State how you would proceed to remove the coal and rob the pillars. *I.—Pa.* (*B*)

Ans.—It is important in this case to keep a manway always open for the escape of the men. The coal in the breasts should not be drawn faster than the work upon the pillars progresses. The safest method to pursue would be to drive a narrow heading up the center of each pillar, which will furnish the escape for the men. Cross-cuts are driven at intervals of 8 or 10 yd., dividing the pillar into sections, each section of pillar being worked to the rise from the cross-cuts. If the conditions will permit, the pillars may be worked from the upper end downwards, the coal being chuted across the manway into the breasts upon either side; but this is not usually practicable. If the pillars are worked from above, cross-cuts will not be required in the pillars, but care will be necessary to keep the manway open for escape. Fig. 3 illustrates some of the methods employed in drawing pillars in steep seams.

Ques. 1617.—Show by sketch the best method of drawing ribs 30 feet wide where the overlying strata are 250 feet thick; giving the reasons for your method; also, explain why some ribs are more difficult to extract than others of the same width. *F.—Pa. (B)*

Ans.—Assuming a flat seam, say 6 ft. thick and lying 250 ft. below surface, the best method of drawing ribs 30 ft. thick in this seam will be to maintain roadways *R*, Fig. 4, upon each side of the rib, giving to each miner 15 ft. of the rib to draw back. As shown in the figure, a shot should first be taken off at each rib next to the roadway after the manner of working a loose end. When this is cleaned up other shots *a* are placed on each

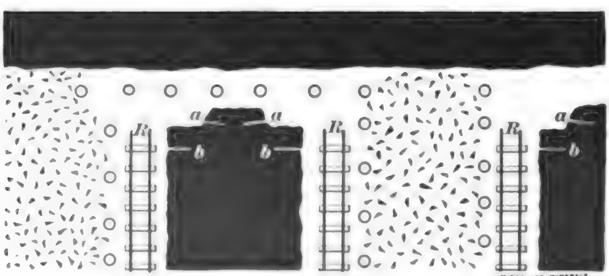


Fig. 4

side to extract the center of the rib. Two shots on each side of the rib should be sufficient to bring the miners together. When the coal is loaded and the roof made secure by timbers, shots *b* are again placed in the rib next to the roadway as before. It should be the aim to draw back several pillars uniformly, and to keep the ends of the pillars square, so that the roof pressure will not bear too heavily upon any of them. The timbers should be drawn a short distance behind the pillar working so as to induce a fall.

The reason that some ribs of the same width are more difficult to extract than others is owing very largely to the character of the coal, depth of cover, and nature of the floor and roof. Where the pillars are thin and the roof

pressure considerable, or where the coal is soft, the pillars become crushed and the coal is then not only difficult but dangerous to extract. Where the pillars are crushed and creviced, blown-out shots are liable to occur in their working, since the energy of the powder is exerted upon the air through the crevices rather than upon the coal. Undermining, in pillar work, should be done with caution.

Ques. 1618.—When extracting a range of pillars of an average thickness of 20 feet, how would you proceed to remove them to insure the safety of the workmen and the mine? *F.—Pa. (B)*

Ans.—Examine the timbering before beginning the work and replace any bad timbers. Avoid weakening the pillars at any point except at the end where the work of robbing is going on. Keep the pillar working in line so that no undue pressure will be thrown on any one pillar, but all the pillars will be treated alike. The pillars should not be taken out too close to the entry pillars for fear of starting a crush.

Ques. 1619.—With ordinary good roof and floor, can pillars be extracted successfully with mining machines? *F.—Pa. (B)*

Ans.—This is possible, but under ordinary conditions of mining, undercutting machines are not adapted to working pillar coal or loose ends. The use of these machines will depend on the room or space available behind the pillar, and between it and the timbers that are left for protection of the machine. However, in the drawing of wide pillars under good roof, undercutting machines can often be used to advantage.

Ques. 1620.—What must be carefully considered before the work of drawing pillars is begun? *I.—Ia.*

Ans.—In general, it is better to draw room pillars back regularly as the rooms reach the limit, to avoid the possibility of starting a creep or squeeze by holding open too large an area. Before room pillars are drawn, however, the question of the effect upon adjoining workings and upon the surface should be carefully considered. Before entry pillars are drawn back, it should be determined definitely whether all the coal has been mined that it is possible to reach from such entries, and whether or not those entries will be required for airways or haulage roads in the later development of the mine. The presence of water in the overlying strata will often affect very largely the question of drawing pillars both in rooms and in entries.

Ques. 1621.—When extracting pillars, how should the general line of face be kept? *F.—Ia.*

Ans.—In regular line to avoid too great roof pressure on any one of the pillars. This line may or may not be parallel to the working face or the entry. When the pillars are drawn back in regular succession, as quickly as the rooms reach their limit, the line of pillar work necessarily makes an angle with the entry.

QUES. 1622.—In starting to pull pillars on an entry that had thirty rooms on it, how would you place your men, and how many places would you work? *F_2.—Ala.*

ANS.—Under ordinary conditions of roof and floor, it is common practice to draw back the room pillars as rapidly as the rooms are finished. It may be more practicable, however, in any given mine to allow the room pillars to stand until all the rooms on that entry are finished, and then draw back all the room pillars at once. Care should be taken to secure a fall of roof as the pillars are drawn. The placing of the men in pillar drawing depends wholly on the conditions relative to the width of the room pillars, the character of the rooms, whether single or double, etc. When double rooms are driven, a track has been carried up on both sides of each pillar and two sets of men can then work conveniently on each pillar.

SQUEEZE AND CREEP

QUES. 1623.—What is a squeeze and what do you consider the best method of preventing a squeeze? *F.—Pa. (A)*

ANS.—A *squeeze* in a mine is the crushing of the pillars due to too great a weight being thrown on them. The first indications of a squeeze are the splintering or nicking of the coal along the ribs of the passageways and chambers. This is followed by cracking of the pillars, which finally crush into small coal, allowing the top to fall. The best method of preventing a squeeze is to leave ample pillars for the protection of the entries and for the support of the roof in the rooms. Care should be taken that too large an area should not be worked out and left standing, but the timber and pillars should be drawn soon after the rooms are worked up, so that the roof will fall and close the rooms, thus relieving the entry pillars of the great weight thrown upon them by the removal of the coal. A squeeze can often be prevented by filling some of the worked-out breasts with culm, which is flushed into the mine with water and held in place by dams built across the mouth of the breasts. In the subsequent working of a mine in which there has been a squeeze, the size of the room and entry pillars should be increased, to avoid a recurrence of the trouble, and all timber should be withdrawn from abandoned rooms, and care taken to secure a fall of roof in such places. When the squeeze has attained an advanced stage, there is little that can be done to stay its progress, as it will probably close the workings in that district in spite of all efforts to stop its progress.

NOTE.—The terms squeeze and creep are frequently used synonymously, but it is well to observe the distinction between the terms as given in Ques. 1623 and Ques. 1624.

QUES. 1624.—What is a mine creep, what causes it, and how can it be prevented? *F.—Pa. (A)*

ANS.—A mine creep may be described as a sagging of the roof or heaving of the floor, in the mine workings. It is caused by the roof pressure being too great for the size of the pillars in connection with soft and weak material

composing the roof and floor, such as fireclay which swells when exposed to the air. In some cases, the nature of the floor is such as to induce creep unless extra wide pillars are left, or the openings driven as narrow stalls. The soft floor or roof permits the pillars either to sink into the floor, or be forced into the roof, pressing out the soft material that fills the openings. A creep is apt to continue until all the excavations are filled and the whole becomes compact enough to resist the weight, unless the openings be flushed with some material such as culm. The best preventive of such a creep is to drive narrow openings with large pillars between and to keep the bottom dry, as water assists in softening and swelling the fireclay.

QUES. 1625.—To what cause or causes can squeezes in mines be traced? *F.—Pa. (A)*

ANS.—Squeezes in mines are due: to too small pillars; too much standing timber in abandoned workings; too large an area standing open; improper timbering; improper and irregular methods of working the coal and of robbing the pillars; improper methods of working contiguous or overlying seams whereby the pillars in lower seams do not come directly under and support those in the overlying seams; irregularity in drawing pillars; improper methods of working in adjoining mines.

QUES. 1626.—What dangers and difficulties are often encountered from a mine squeeze? *F.—Pa. (B)*

ANS.—The dangers attending a squeeze or creep, are as follows: if the squeeze is very sudden, men may be imprisoned and lives lost; if explosive gas is present it may be forced out upon naked lamps, or air may be blown along the passageways with sufficient force to damage them; the system of ventilation may be entirely destroyed; overlying workings may be injured; a squeeze that may be slight when it starts may extend to an entire mine, or even to adjoining mines.

A mine squeeze is not always attended with immediate danger, much depending on the rapidity with which the weight comes on the pillars. At times, the action of the squeeze is very sudden and severe. Pillars are crushed and heavy falls occur in the rooms and entries, which often completely close the workings over large areas or render their working extremely dangerous. The difficulties then encountered are the maintaining of the rooms and entries in safe condition. If the action of the squeeze is at all violent, the working places are usually abandoned as unsafe, and every effort is made to cause a fall of roof in the rooms and working places in the hope of preventing the destruction of the entry pillars.

QUES. 1627.—What are the causes of falls of roof, and how would you make an inspection to determine the security of the roof in a mine? *F.—Ia.*

ANS.—The removal of coal is the immediate cause of falls of roof; insufficient timbering, or slips or weakness of the roof strata also cause the

roof to fall; too great a width of opening as compared with the strength of the roof is another frequent cause of falls. Roof falls are induced also by squeeze, arising from a too rapid removal of the coal, or too large a standing area, or too small a percentage of pillar coal left for the support of the roof, improper timbering, etc. Roof inspection requires the utmost caution, and the work should be entrusted only to experienced men. The roof is sounded with a hammer or pick at frequent intervals, to determine any weak places where a hollow sound is given out when the roof is struck. Dependence must not be placed wholly on the sound, however, although a hollow sound is a good indication of the roof being heavy. Slips and faults in the roof should be carefully observed. The most dangerous slips are those running parallel with the working face. Roof inspection includes a careful inspection of the amount and the condition of the timber supporting the roof and the kind and amount of timber on hand at the working face.

QUES. 1628.—In case a squeeze occurs in a mine of which you had charge, endangering a heading and threatening to shut off part of the work, how would you proceed to stop its progress?

F_1.—Ala.

ANS.—In case the creep has progressed so far as to manifest itself on the entry by the nicking or chipping of the ribs of the entry, and by the breaking of the entry timber, there may be some question as to whether the squeeze can be controlled. Radical measures should at once be adopted. All standing timber should be withdrawn from adjoining abandoned places, and, where practicable, room pillars in the affected district should be drawn back and every effort made to induce a fall of roof in these places. At the same time, shots should be placed in the roof, just inside of the mouth of each room, so as to break the roof over the entry pillar and thus relieve these pillars of the excessive weight thrown upon them; cribs may be built outside of the affected portion. Arrangements should be made to leave larger pillars in the future working of the mine.

QUES. 1629.—In case of a squeeze occurring in a mine under your charge, at what stage of its progress would you consider yourself justified in stopping operations and withdrawing the workmen?

F.—Pa. (A)

ANS.—It is difficult to give a definite answer to this question, as the conditions are different in every case. There are times when the timbers will be crushed and broken as quickly as they are put in, and at times the floor of the roadway will heave so rapidly as to afford little opportunity to save the tracking, and yet the conditions of the roof and of the coal are such that there is no immediate danger to the lives of the workmen employed in the necessary work of securing the roadways or saving material. It is always wise to abandon work on the coal at the face of breasts during the action of a severe squeeze. This is imperative under many conditions of roof and coal, in order to avoid the possibility of accident from falls of

roof or coal. It is not, however, necessary even then to withdraw the men working on the airways and in other parts of the mine. During the squeeze, every reasonable effort should be made to withdraw standing timber in the waste or gob, and work out such pillar coal as can be done safely in order to cause a fall of roof and thereby relieve the entry pillars. Shots should be placed in the mouths of abandoned rooms so as to break the roof over the entry pillars. Timbers should be set and cogs should be built in all places along the roadways where it is possible to reinforce the pillars thereby. This necessary work should not be abandoned as long as there is reasonable hope of controlling the squeeze.

CHAPTER XVIII

TIMBERING

SIZE OF PROPS

QUES. 1650.—Explain how you would determine the safe working load for a seasoned hemlock mine prop 10 inches square and 10 feet long, assuming that the crushing load per square inch is 5,300 pounds. *I.—Pa. (A)*

ANS.—A safe rule to adopt in regard to post timbers in mines is as follows: In order that a post shall present an equal resistance to crushing and bending, the diameter of a round post should be one-twelfth of its length; and the side of the square post should be one-fifteenth of its length. When the relative length of a post is greater than is expressed in this rule, the post will bend before it will crush, and vice versa. The length of the square post given in this example is only twelve times the width of one side, and, hence, the stick will begin to crush on the ends before it will bend. The load producing crushing in this case is

$$\frac{10 \times 10 \times 5{,}300}{2{,}000} = 265 \text{ T.}$$

The safe working load for this prop may be considered as about one-third of the crushing load, or about 90 T.

QUES. 1651.—If it requires a prop 6 inches in diameter in a seam 5 feet thick, to be equally effective what would be the diameter of the prop if the thickness of the seam increased to 9 feet? *F.—Pa. (A)*

ANS.—The diameter of post timber should be proportional to the thickness of the seam or length of the post in order to present the same resistance to crushing and bending; calling the required diameter x, $\frac{x}{6} = \frac{9}{5}$; and $x = 6 \times \frac{9}{5} = 10.8$, say 11 in.

QUES. 1652.—What is the relative strength of two props, one 6 feet long and the other 12 feet long? *F.—Pa. (A)*

Ans.—Assuming that the diameters of the two props are equal and such that each prop will bend before it will crush, their strengths will vary inversely as the squares of the lengths of the posts. The ratio of the lengths being $\frac{6}{12}$ or $\frac{1}{2}$, the ratio of the strengths of the two props will be $\left(\frac{2}{1}\right)^2 = \frac{4}{1}$. That is to say, a 6-ft. prop of such a diameter that it will bend before it will crush, will possess four times the strength of a 12-ft. prop of the same diameter under like conditions. In case, however, the diameters of these posts are proportional to their lengths, their strength will be directly proportional to the squares of their lengths; in other words, a 12-ft. prop 12 in. in diameter will sustain $\left(\frac{12}{6}\right)^2 =$ four times the load of a 6-ft. prop 6 in. in diameter.

SETTING PROPS

Ques. 1653.—When would you consider a prop to be well stood? How many rows of props should there be placed in a chamber 30 feet wide? *F.—Pa. (B)*

Ans.—In a flat seam, the props should be placed perpendicularly so that the weight may act directly downwards through the center of the prop. The bottom should be placed in a shallow foot-hole, and the top and bottom of the prop should be carefully squared so that contact between the ends of the prop and the top and bottom rock may be good. If only a portion of the bottom of the prop is supported, or only a part of the top is in contact with the roof, the entire weight will come on only a portion of the cross-section of the prop. If the props are cut to the exact length between the roof and the floor, it is impossible to give a rigid and perfect contact between the ends of the prop and the roof or floor; for this reason, a wedge-shaped cap should be placed above the prop so that it may be firmly driven in place. Such a cap also supports a greater section of the roof, and in case there is a slight unavoidable settlement of the roof, or swelling in case of a fireclay, if the cap piece is of soft timber the prop may be forced into it and not split. If it is not possible to make a rigid contact between the bottom of the prop and the floor, a foot-piece may be used, although this is not commonly done. Sometimes some loose dirt is placed in the foot-hole to act as a cushion for the prop, particularly when the prop sets against fireclay, which swells. In longwall mining, where the roof necessarily sags, the bottom of the prop may be placed on a built-up mound of dirt to allow for the inevitable sinking of the roof.

The number of rows of props necessary in a chamber 30 ft. wide will depend on the thickness of the seam or the length of the post. In order that the post may present equal resistance to crushing and bending, the diameter of the post, in inches, should equal its length in feet. In a seam 6 ft. thick, the diameter of the small end of the post should be 6 in.; its area is then $.7854 \times 6^2 = 28.27$ sq. in. Multiply this area by the crushing

strength of the timber, in pounds per square inch, and the product will be the entire load that the post will support without crushing or bending; in this case, for oak timber,

$$28.27 \times 7{,}200 = 203{,}544 \text{ lb.}$$

The weight of the top, which must be supported by the post, cannot, of course, be determined and the following method, which is only an approximation, is sometimes used. The number of rows of posts must be determined largely by experience and depends entirely on the thickness of the seam and the character of the top rock. Assuming that the height of the overarched material is equal to the breadth of the opening and the weight of the material to be 160 lb. per cu. ft., the roof pressure per square foot supported by the timbers in this case is approximately

$$160 \times 30 = 4{,}800 \text{ lb. per sq. ft.}$$

The area supported by each 6-in. post should, then, be

$$203{,}544 \div 4{,}800 = 42{,}405 \text{ sq. ft.}$$

and the distance of the posts apart is $\sqrt{42.405} = 6.5$ ft. The number of rows of props in this breast perpendicular to the face will therefore be $\frac{30}{6.5} - 1$ = say 4 rows.

QUES. 1654.—Show by a sketch how to set props in a level seam. *F.—Pa. (B)*

ANS.—Fig. 1 shows a prop set perpendicularly to the seam with the bottom of the prop placed firmly on the bottom rock without any foothold shown. The cap *b* gives a good bearing between the top of the prop and the roof and also enables the prop to be driven firmly in place; it also gives a greater bearing to the roof surface, and if of soft wood allows a slight settlement without cracking the props. Fig. 2 shows a method used in longwall work, where it is desired that the roof may settle slightly and also where it is advisable to have the bottom of the prop loose so that the prop can be easily drawn. This same result is accomplished in England by tapering the bottom of the prop, as shown in Fig. 3. This tapering permits the lower end of the timber to fur as the weight comes on it and the post is not so apt to split.

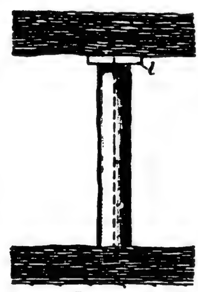


FIG. 1

QUES. 1655.—What methods would you adopt in timbering: in rooms where the roof and bottom are hard? in rooms where the roof is hard and bottom soft? where the roof and bottom are soft? *F.—Pa. (B)*

ANS.—Post timber in rooms where roof and bottom are hard should usually be set firmly with the bottom of the prop firmly against the rock and in a foothold, while the top is held firmly by a cap tightly wedged against the top rock.

Where the roof is hard and the bottom soft, the worst condition relative to the support of the roof is realized. The hard roof refuses to break and there is an extra pressure thrown on the pillars, which are usually large; the soft bottom heaves. In the case of wide pillars, but little timber is required, what is used may be set on substantial foot-boards to give a sufficient bearing for the post on the soft bottom.

FIG. 2

Where the roof and bottom are both soft, the posts at the face of rooms are usually provided with good caps and foot-boards. Here, much timber is required at the face, and cribs are often necessary to protect the roads that are laid close to the rib.

Fig. 2 shows a method of setting the foot of a post upon a foot-board, and this board in turn upon a small pile of dirt; the object of this is to allow the post gradually to settle without breaking if the greatest pressure comes on it at first, as is sometimes the case, particularly with a roof that slacks or swells. Fig. 3 shows a tapered post intended to serve the same purpose.

FIG. 3

QUES. 1656.—What would be your method of timbering in rooms that are driven 21 feet wide, the roof being good and firm? *F.—Pa. (B)*

ANS.—The method of timbering will depend much on the character of the floor and coal and thickness of the seam. Under favorable conditions, a uniform system of post timbering should be adopted, the posts being set in rows parallel to the face, and at a regular distance apart. Each post should be supplied with a good cap piece of suitable thickness, and having a width at least equal to the diameter of the post, and the post should be driven firmly in place. The timbering of a room should be promptly and regularly performed; when it is necessary to set a post, the work should not be deferred.

QUES. 1657.—In timbering a room, how far apart would you place timbers, under a fair roof? If the top is bad, how should they be placed? How would you set a prop to carry the greatest possible weight? *F_1.—Ala.*

ANS.—The distance apart of the props depends entirely on the height of the seam, the width of the opening, and the size and character of the timber available. For a seam 6 ft. thick, the props should be not less than 6 in. in diameter to give the best results; for a 4-ft. seam, not less than 4 in. in diameter.

There is no accurate way of calculating the distance apart of the props, and the answer must be based largely on experience.

To carry the greatest possible weight, a prop should be set perpendicularly to the seam.

SETTING PROPS IN INCLINED SEAMS

QUES. 1658.—How would you set a single post on a pitching seam? *F_1.—Ala.*

ANS.—A place is first chosen affording the greatest support for the roof, and a foothold B, Fig. 4, is cut a few inches deep in the floor. When the roof and floor are apt to swell, a little coal slack or other soft material is frequently placed in the bottom of the foothold to prevent the swelling of the rock from cracking the post. The length of the post is made slightly greater than the height of the roof above the bottom of the foothold, after making due allowance for the thickness of the cap and for the slack placed in the bottom of the hole. In inclined seams, Fig. 4,

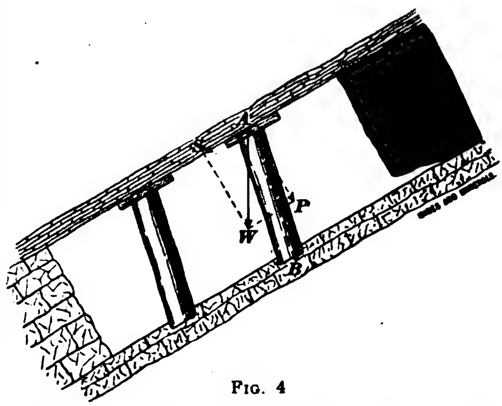


FIG. 4

the roof weight $A\ W$ acting vertically may be resolved into a sliding force $A\ S$ parallel to the seam and a normal pressure $A\ P$ perpendicular to the bedding planes. A post to resist this normal pressure should be set at right angles to the roof and floor of the seam; but owing to the tendency of the roof in inclined seams to slip downwards, it is necessary to set posts in such seams leaning slightly up the pitch from a normal position, as shown in the figure, so that the slipping of the roof will tighten the post; this is termed *undersetting* the post. The amount that the post inclines up to the pitch from a normal position varies, with the inclination and character of the seam and contiguous strata, from 1° to 9°. To set the post, when all is ready and the post has been cut to the proper length and squared at both ends, it is laid on the floor, often with its small end just above the foothold and the larger end extending up the pitch. The upper end of the post is then raised, its foot being placed in the hole prepared for it, and the cap piece above it against the roof. The head of the post and the cap are then driven to place by a sledge. The cap should be of soft wood and 2 or 3 in. thick.

QUES. 1659.—Explain how you would proceed to set a prop to carry the greatest weight possible in a seam pitching from 5° to 15°, and also from 50° to 70°. *I.—Pa. (A)*

ANS.—To set a prop or post in an inclined seam, proceed as described in the answer to Ques. 1658. In a seam pitching from 5° to 15°, the post should be underset or inclined up the pitch at an angle of, say 2°. The cap itself should be of soft wood, from 2 to 3 in. thick, wide enough to cover the top of the post, and, say 18 in. long. In a seam pitching from 15° to 70°, props should be underset, say 9° or 10°. In this case, the length of a prop should be equal to 1.015 times the perpendicular length measured, as previously described; thus, when the perpendicular distance measured between the roof and floor of the seam, less the allowance for the thickness of the cap, is, say 70 in., the length of the prop will be $70 \times 1.015 = 71.05$, or a full 71 in.

QUES. 1660.—What, in your opinion, is the best method of timbering when the top rock is hard and inclined to creep, the coal being free, and the seam having an inclination of 10°? State which requires the larger pillars, a hard or a soft roof. *F_1.—Ala.*

ANS.—Under the conditions mentioned, the method of timbering to be employed is not so important as the relative sizes of pillar and opening to be adopted. There may be a tendency of the coal to run. The breasts should be driven up narrow, say 14 ft. wide with pillars varying from 8 to 10 yd. in width between them. The track should be maintained close to the rib whether the breast is driven across the pitch to reduce the grade, or whether a gravity incline is employed and the road is carried up on the full pitch of the seam. There will probably not be much timber required, save an occasional post, which should be slightly underset in the seam. The main point is to see that the pillars are of sufficient thickness to avoid creep, and that the breasts are narrow enough to avoid the running of the coal. When the openings have been driven up to their limit the pillars are drawn back in the usual manner. A hard roof requires the larger pillars.

COLLARS OR CROSS-TIMBERS

QUES. 1661.—We have two stringers of the same material, one being 8 in. × 10 in., and 15 feet between the points of support, and the other 6 in. × 12 in., and 17 feet between the points of support; which stringer will bear the greater load equally distributed along its length? *I.—Ill.*

ANS.—For the same kind and quality of timber, the loads the beams will support are proportional to the expression $\frac{b\,d^2}{l}$, or $\frac{breadth \times (depth)^2}{length}$. The values for this expression for these two beams, respectively, are

$$\frac{8 \times 10^2}{15} = 53.33, \text{ and } \frac{6 \times 12^2}{17} = 50.82$$

The first of the two beams mentioned will therefore probably support a somewhat greater load.

QUES. 1662.—What load will break a white-oak timber 8 in. $\times$ 12 in. and 15 feet between the supports, if the load is equally distributed along the length? *M.—Ill.*

ANS.—The breaking load for a rectangular beam supported at both ends and loaded uniformly is,

$$W = \frac{16\,f\,I}{l\,d};$$

in which

W = load supported by beam, in pounds;

f = fiber stress of material, in pounds per square inch (= 8,500 for white oak);

I = moment of inertia of cross-section of beam $\left(= \frac{b\,d^3}{12} = \frac{8\times 12^3}{12} = 1{,}152\right)$;

l = length of beam, in inches;

d = depth of beam, in inches.

Substituting in the formula

$$W = 16\times\frac{8{,}500\times 1{,}152}{15\times 12\times 12} = 72{,}533 \text{ lb.}$$

$$72{,}533 \div 2{,}000 = 36.27 \text{ T.}$$

QUES. 1663.—How much greater load will a cross-bar 6 feet long, 9 inches wide, and 1 foot in depth sustain than one of the same length and breadth and 10 inches in depth? *F.—Pa.* (*B*)

ANS.—The strength of timber cross-bars varies as the breadth multiplied by the square of the depth and this product divided by the clear length of the span; or as the expression $\frac{b\,d^2}{l}$. In this case, since the length and breadth of the bars are equal, respectively, the strength is proportional to the square of the depth. Then, calling the strength of the bar 10 in. in depth unity or 1, and that of the 12-in. bar x,

$$\frac{x}{1} = \left(\frac{12}{10}\right)^2 = 1.44;$$

that is to say, the 12-in. beam is 1.44 times as strong as the 10-in. beam.

QUES. 1664.—What will be the difference in the strength of two pitch-pine timbers, each 9 feet long and supported at both ends, the one being 10 in. $\times$ 10 in., and the other 8 in. $\times$ 12 in., placed on edge? *I.—Pa.* (*B*)

ANS.—For the same span, the strength of timbers used as beams is proportional to the width of the beam and the square of its depth; hence, the strength of the two beams in this case will be as $10\times 10^2 : 8\times 12^2$, or expressed fractionally

$$\frac{10\times 10^2}{8\times 12^2} = \frac{1{,}000}{1{,}152};$$

that is to say, for every 1,000 lb. the $10''\times 10''$ beam will support, the $8''\times 12''$ beam will carry 1,152 lb.

QUES. 1665.—We have two cross-bars of the same material and sectional size, supported at their ends and loaded uniformly along their entire length, one being 6 feet and the other 7½ feet between the points of support; which will bear the greater load? If the shorter can safely bear a load of 5 tons, what will be a safe load for the long bar? *M.—Ill.*

ANS.—The strength of bars varies inversely as their clear length of span; hence, the bar having the shorter span will bear the greater load. If the bar whose span is 6 ft. will safely carry 5 T., the bar whose span is 7½ ft. will carry 4 T.

QUES. 1666.—What is the comparative strength of two round-timber cross-bars or stringers, one being 12 inches in diameter and 8 feet long, the other 16 inches in diameter and 10 feet long? *M.—B. C., Canada*

ANS.—For beams of round timber, the strength of the beam is proportional to the cube of its diameter, and inversely proportional to the length of the clear span; or the strength of such beams is proportional to the expression $\frac{d^3}{l}$, and the ratio of the strength of two such beams is equal to the ratio of the values of this expression for each beam. Calling the strength of the first timber unity or 1, and that of the second timber x,

$$\frac{x}{1} = \frac{16^3}{10} \div \frac{12^3}{8};$$

and
$$x = \frac{16^3}{10} \times \frac{8}{12^3};$$

and
$$x = \left(\frac{16}{12}\right)^3 \times \frac{8}{10} = .8\left(\frac{4}{3}\right)^3 = 1{,}896+$$

Hence, the timber 16 in. in diameter and 10 ft. long is 1.896 times as strong as the timber 12 in. in diameter and 8 ft. long or, if the 12-in. stick 8 ft. long will carry a safe load uniformly distributed of, say 20 T., the 16-in. timber 10 ft. long will carry 20×1.896 = say 38 T.

QUES. 1667.—If a collar or cross-beam 10 inches in diameter and 6 feet between notches bears a certain load, what should be the diameter of a collar 12 feet between notches to bear the same load? *I.—Pa. (A)*

ANS.—In this case, if the unit load or load per foot of length is the same on both beams the diameter of the beam should vary as the cube root of the square of the length or distance between supports. In other words, the cube of the diameter ratio is equal to the square of the length ratio in such beams. Calling the required diameter x,

$$\left(\frac{x}{10}\right)^3 = \left(\frac{12}{6}\right)^2;$$

and
$$x = 10\sqrt[3]{4} = 15.87, \text{ say } 16 \text{ in.}$$

Ques. 1668.—If a gangway collar 6 feet long and 8 inches in diameter is required to support the roof in a certain mine, what will be the diameter required to support a similar roof on a turnout 12 feet wide? *I.—Pa.* (*A*)

Ans.—Assuming the span of the collar to be 6 ft. in the first case, and 12 ft. in the second case, and using round timber; since the load per foot of length is constant, and therefore the total load on each collar is proportional to its length, the square of the length of the span varies directly as the cube of the diameter of the collar, for round timber; or, in other words, the cube of the diameter ratio is equal to the square of the length ratio. Hence, calling the required diameter for the 12-ft. timber x, we have

$$\left(\frac{x}{8}\right)^3 = \left(\frac{12}{6}\right)^2;$$

and $$x = 8\sqrt[3]{4} = 12.7, \text{ say 13 in.}$$

DOUBLE TIMBERS

Ques. 1669.—Explain what is meant by double timber in a mine. Make a sketch of a timber set showing how you would wedge it, and give reasons for wedging thus. *I.—Ia.*

Ans.—The term *double timber* in mining, refers to a timber set composed of two legs and a cross-bar or collar. An entry or passageway is double timbered when such timber sets or frames are used, in distinction from post timbering, when a single post and cap are used.

Fig. 5

Fig. 5 shows the manner of wedging a set of timbers to produce the best results, the wedges being driven on each side of the center and nearly over the legs, so as to throw the roof pressure on the legs instead of on the collar or cross-bar as is done when the wedges are placed over the center of the cap.

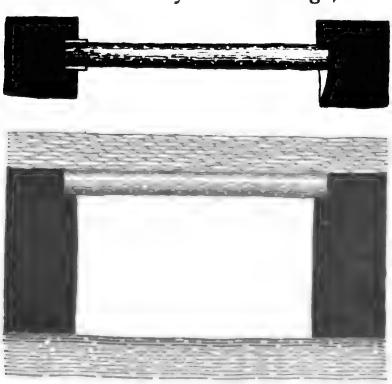


Fig. 6

Ques. 1670.—Describe the various methods of timbering for securing the top and sides in mines. State the pitch of legs and props in relation to the pitch of the strata.

Ans.—Mine timbering consists of two general types, post timber and timber frames. Post timber and the method of setting it have been described in answer to Ques. 1654. Timber frames are employed in openings

where the roof requires more support than is given by a simple post. When the roof alone requires support, and the sides are hard and firm, a cross-bar is sufficient, the ends of the bar being placed in hitches, Fig. 6. Sometimes the bar rests on a prop at one end and is needled in at the other, *a*, Fig. 7. When the sides cannot be depended on to support the cross-bar, it is supported at each end by a prop or leg inclined at a slight angle toward the center of the road and notched into the cross-bar only enough to keep it in place, *b*, Fig. 8. Where the roof is frail, lagging is used above the cross-beams, reaching from frame to frame. Where the ribs are weak and tend to fall or need support, this lagging is carried along the sides also. The batter of the legs in a timber frame should be generally about 2 inches per foot of height. Where the bottom is soft, the timber frames are set on longitudinal or cross mud-sills. The longitudinal sills are as shown in Fig. 9 and the cross-sills, in Fig. 10. When the side pressure is considerable, the timbers are arranged as shown at *A*, *B*, *C*, Fig. 11. The distance apart of the sets depends on the character of the ground timbered. In loose ground, the timber sets are sometimes placed skin to skin, Fig. 12.

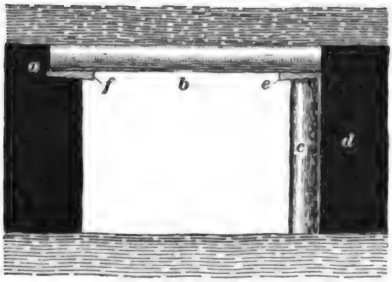


FIG. 7

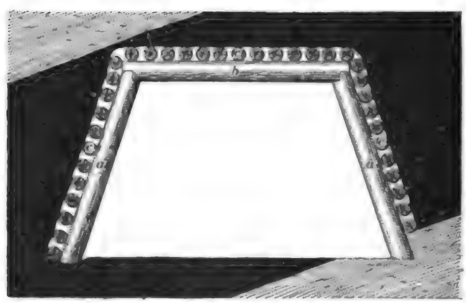


FIG. 8

QUES. 1671.—An entry is 8 feet wide at the top, 12 feet wide at the bottom, and 6 feet high; what length must the legs of a timber set be; the leg is notched into the collar at the top $\frac{1}{2}$ inch, and into the mud-sill $\frac{1}{2}$ inch? *M.—Ill.*

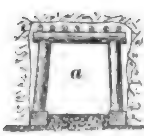


FIG. 9

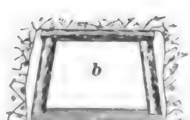


FIG. 10

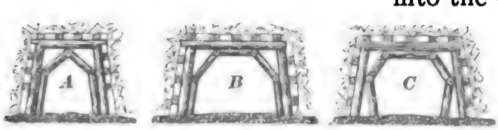


FIG. 11

ANS.—Assuming that the 6 ft. of height in the entry includes the depth of the cross-beam and that of the mud-sill, and allowing 8 in. for the former and 10 in. for the latter, the vertical height of the post is

$$6 \times 12 - (8 + 10) + 1 = 55 \text{ in.}$$

The post on each side leans in a distance

$$\frac{12 \times (12-8)}{2} = 24 \text{ in.}$$

Then, the length of the inclined leg is

$$\sqrt{24^2 + 55^2} = 60 \text{ in.} = 5 \text{ ft.}$$

QUES. 1672.—How would you timber an airway when the bottom is soft or wet? *F_1.—Ala.*

ANS.—The bottom being soft and wet, the timber frames should be set upon sills running either longitudinally or across the entry, as described in the answer to Ques. 1670. If the coal is hard, it may be practicable to omit the sills and use short legs, setting the short legs of each set of timber in hitches cut in the coal. The road may then need to be corduroyed by laying track ties close together, across the road under the track. In any case, the road should be well drained by a good ditch.

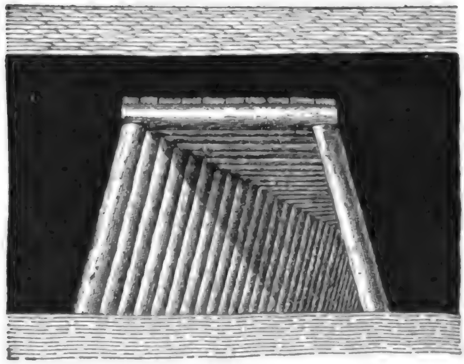


FIG. 12

QUES. 1673.—Describe the various methods of timbering slopes and gangways, etc. *F.—Pa. (A)*

ANS.—The methods of timbering slopes and gangways differ according to conditions of roof, floor, and seam. A flat slope is timbered like a gangway or level excepting that the timber frames are underset similarly to props in inclined seams. The frame should incline up the pitch from 1° to 9°, according to the pitch of the seam. When the inclination of a slope is nearly vertical, it is timbered similarly to a shaft. In steep seams, the track on the slope has a tendency to slip down the slope. To prevent this, it is customary to use occasional long track ties and to lodge these in hitches cut in the ribs on either side of the gangway. In other cases, braces or struts are used reaching from the rib on either side and resting in hitches cut in the side or against side posts or the side and center posts.

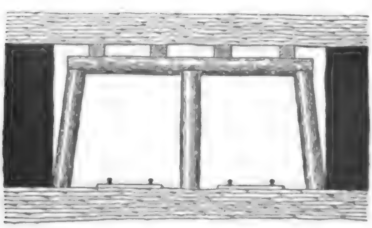


FIG. 13

QUES. 1674.—Draw a sketch showing how you would frame a set of timber for a slope where you expected to use a center post and two tracks. *F_1.—Ala.*

Ans.—Fig. 13 shows a timber set framed for a double-track road and having a center post. The figure shows the manner of wedging the timber against the roof; also, a common form of joint above each post, the under side of the collar or cross-beam being boxed or dapped ½ in. in depth above each post, and the edges of the box beveled to fit the beveled shoulder at the top of the post; this bevel prevents the splitting of the collar at this point when the weight comes on the timbers. In case of side pressure, the side posts are dapped 1 or 2 inches into the collar.

SHAFT TIMBERING

Ques. 1675.—Describe the several methods of timbering shafts, slopes, gangways, chutes, and headings. State the advantages of each method, and under what conditions of strata you would apply them. *I.—Pa. (A)*

Ans.—In firm rock strata, little timbering is required in shaft sinking. Cross-buntons of pine, hemlock, or oak (usually 6 in. × 8 in.) are employed. These buntons are spaced about 6 ft. apart, and set in hitches cut in the rock. They are firmly wedged in line, from the top to the bottom of the shaft, and furnish a support for the guides, pipes, and signal wires required in the shaft, as well as for the partition separating the hoistway from the manway or pumpway. In frail or loose material, shaft lining or curbing is required. The curbing may be continuous from top to bottom, or it may be, and in deep shafts often is, changed to conform to the character of the strata at any point of the sinking. Shaft lining is, of course, employed at all points where the strata are not self-supporting, and is carried down until a hard stratum is reached of sufficient thickness to warrant the abandoning of the shaft lining. Cross-buntons are then used while passing through the harder strata, and lining again introduced if softer strata are encountered below. When this is done, arrangements must be made for the handling of the water coming from the strata above the hard pan, either by the laying of a water-tight curb, or building a coffer dam, which is simply a tight shaft lining of heavy timbers, laid with a tar-felt joint to exclude the water. Sometimes the timbers forming the coffer dam are mortised together to provide a water-tight joint. It is important to leave weep holes, or to provide for the drainage behind the shaft curbing at this point, by suitable pipes that will conduct the water to the bottom of the shaft. In some cases, there is excavated in the hard pan behind the shaft curbing, a sump of sufficient size to hold the water that accumulates, and a pump is located at this point for raising the water to the surface. By this means, there is a considerable saving of power by not allowing the water to drain to the bottom of the shaft. In this arrange-

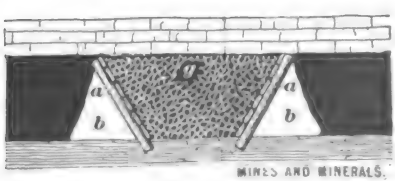


Fig. 14

ment, it is usually necessary to excavate a small manway entirely surrounding the shaft. In general, the lining of shallow shafts is made continuous from top to bottom, where lining at all is required.

The timbering of a steep slope is similar to that of a shaft as just described; the timbering of a flat one is similar to that of a gangway or entry and is fully described in answer to Ques. 1673.

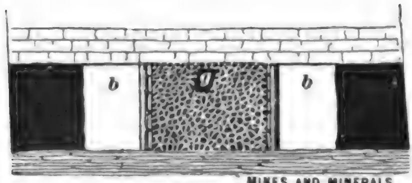


FIG. 15

The timbering of the loading chutes in battery working is similar to the timbering of slopes, but the timbers are usually shorter, and set closer together. A line of posts is usually set on one or both sides of the breast, above the loading chute, a short distance from the rib, to form the manways *b*, *b*, Figs. 14 and 15. Sheathing planks are spiked to the inside face of the posts to form the sides of the chute. In some cases, the posts are inclined so as to lean against the rib (Fig. 14), forming a triangular-shaped passageway; such timbers are known as *jugulars*. Headings or cross-cuts are not usually timbered, but if so, the timbering is similar to that in a gangway.

TIMBERING

QUES. 1676.—How would you notch the timbers for the lining of a shaft, and what advantage is gained by notching them in this way? *M.—Ill.*

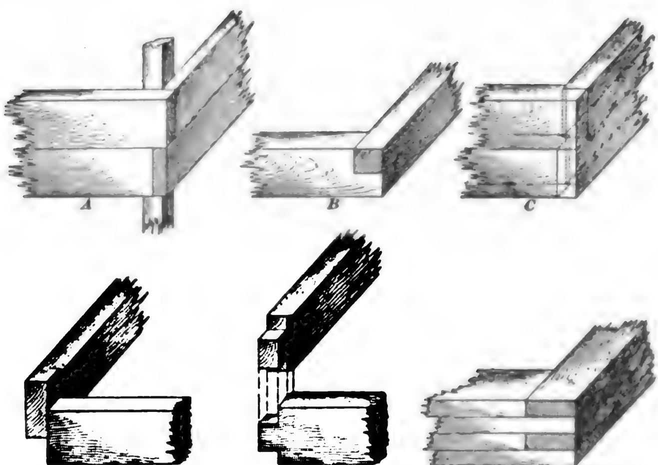


FIG. 16

ANS.—Fig. 16 shows several forms of timber joints employed in shaft sinking. Another form of joint frequently used, is shown in Fig. 17.

Each of these joints possesses particular advantages. The method of framing shown at *A*, Fig. 16, adapted to shallow shafts, requires no framing other than squaring the timbers to the proper length, and is readily and quickly put in place. The form shown at *B* is a simple form of notching where there is heavy side pressure. At *C* and *D* are shown two forms of notching that can be readily sprung into place, and are therefore adapted for the curbing of strata that are not self-supporting, and where space for curbing is limited. The form *C*, where the sets alternate, will resist greater side pressure than that at *D*, since in the latter all the end timbers are the same length and are sprung into place, while in the former, the side and end timbers are alternately sprung into place, thereby equalizing the resisting power of the sides and ends of the shaft. The form shown at *E* is an expensive but efficient joint capable of withstanding great side pressure. The form of curbing shown at *F* is principally used in passing through quicksands, where the curbing must be kept close down to the bottom of the shaft. The form of joint shown in Fig. 17, like that shown at *E*, Fig. 16, is an expensive but a very efficient joint, capable of withstanding great side pressure.

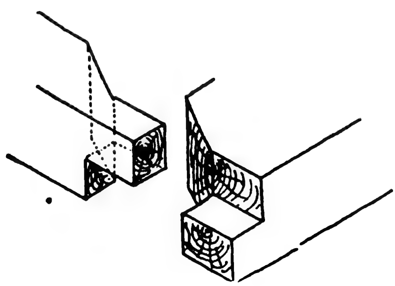


Fig. 17

Ques. 1677.—In which case, in your opinion, does the greater necessity exist for timbering, when the shaft is sunk through measures pitching 70° or through the same measures pitching 5°?

M.—B. C., Canada

Ans.—Other things being equal, there is the greater necessity for timbering where the inclination of the measures is steeper, or in the 70° pitch. The reason for this is that the line of fracture, which takes a general direction across the strata, draws more across the shaft as the pitch of the strata increases.

REPLACING TIMBERS

Ques. 1678.—How would you proceed to replace a set of broken timbers in the mouth of a slope or drift? Explain fully, taking into account the different conditions of the top, sides, and bottom.

F_1.—Ala.

Ans.—It is usual, in replacing a set of broken timbers, not to disturb the old timbers until after the new set or sets have been placed in position beside the old ones, when this can be done. The removal of the old timbers will often cause a fall in the passageway, and before anything is done, therefore, a careful examination should first be made to ascertain the probable

result of the removal of the timbers. When the old timbers are removed either before or after the new set is in position, all loose pieces that are liable to fall should be carefully taken down or secured in such a manner as to prevent a possible accident occurring later. In setting the new timbers, these having been already framed, a leg is first placed in position on one side of the entry or passageway, and one end of the collar raised and placed on top of this leg; the other end of the collar is then raised and the second leg placed in position beneath it. The set is then arranged and temporarily wedged so as to secure its position. The old timbers are now removed, and after taking down any loose pieces of slate, the new timbers are finally and firmly wedged. In replacing a set of broken timbers, ascertain, if possible, the cause of the breaking by carefully observing the timbers. It may be that the roof pressure was thrown too heavily on the center of the collar by wedging at that point instead of the wedges being placed over the legs.

QUES. 1679.—When the timbers in a drift are broken and it is necessary to replace them and enlarge the opening, how would you instruct the workmen to proceed with the work? *F.—Pa.* (*B*)

ANS.—The work should begin at the mouth of the drift and proceed inby, except when extraordinary conditions require otherwise, for the reason that by so doing the men are working outside of a possible fall of roof, and haulage is performed on a good road and under a safe roof. Not more than one or two sets of the old timbers should be removed at one time, and the new timbers put in their place as quickly as the work can be squared up and trimmed. Where the roof is particularly bad, false sets or temporary timbers may be placed to prevent a large fall of roof, and permanent timbers can be placed in position here and there as opportunity may afford, before all the broken sets are taken out.

QUES. 1680.—How would you proceed to timber a gangway that had caved, if two or three sets of timber were broken down; the coal being free and liable to run? *F.—Pa.* (*A*)

ANS.—This question is similar to the preceding question. The old timbers that are broken should not be disturbed until every precaution has been taken to prevent a fall of loose material in the roof and to secure the coal. The lagging over and behind the timbers should be braced, if practicable, before the sets of broken timber are removed. Each set of broken timbers should then be carefully removed and replaced, in turn, by a new set previously prepared.

QUES. 1681.—A shaft bottom 16 feet wide and 200 feet long, is timbered with 14″ × 14″ cross-bars set 2 feet between centers. The roof is badly broken above, causing a great deal of weight on the bars, some of which are badly decayed. We wish to replace those with new ones of the same size. Describe, in detail, how you

would direct such work to be done at least expense, yet insuring the safety of the workmen. *F.—Ind.*

Ans.—It will be necessary, in order to avoid as much as possible the falling of the roof, to place each set of new timbers in position before taking out the old set. The timbers being 14 in. wide, and set 2 ft. center to center, the space between them is $(2\times 12)-14 = 10$ in. Before a new set of timbers can be placed, it will be necessary to remove one set of the old timbers in order to make room for the new set. Or, if this cannot be done without causing a fall it will be better to wedge two of the old sets apart a sufficient distance to permit a new set of timbers being placed between them. When this has been done, one of the old sets of timbers next adjoining may then be removed carefully, so as to cause as slight a fall of the loose material above the timbers as possible. It will now be possible to place another new set of timbers in position, after which a second set of the old timbers is carefully removed as before. In this manner, the work proceeds until the retimbering is complete.

CUTTING TIMBER

Ques. 1682.—What do you consider the best time of the year for cutting mine timbers? Give reasons. *M.—Ill.*

Ans.—The most favorable months of the year for cutting mine timber are December, January, and February. During these months, there is comparatively little sap in the tree. In temperate climates the circulation of sap in forest timber has practically ceased toward the close of December and starts again about the middle of the following February. If timber is cut when the sap is circulating through the tree, rapid decay of the timber ensues from the fermentation of the sap. If cut during the winter months, the timber is more readily seasoned by the drying out of what sap is present and seasoned timber will last fully one-quarter longer than green timber. Another argument in favor of cutting timber during these months is that it is much easier to secure workmen, and transportation to the mines is generally cheaper. The only argument in favor of cutting timber in the summer season is the employment thus given to miners during the dull season in the mines.

CHAPTER XIX

STEAM AND STEAM BOILERS

STEAM DEFINITIONS

QUES. 1700.—Define unit of heat. *H.—Ill.*

ANS.—The unit of heat employed in the United States and Great Britain is that known as the British thermal unit, and is the quantity of heat required to raise 1 lb. of water 1° F., at the maximum density of the water which corresponds to a temperature of 39.1° F.

QUES. 1701.—What is steam, and how is it produced? What is meant by high-pressure and what by low-pressure steam? *H.—Ia.*

ANS.—In its broadest sense, steam is water in the form of vapor, or, in other words, vaporized water. Since water vaporizes at all temperatures, the temperature of steam, in this sense, even at sea level, may be less than 212° F. In its more common use, the term steam, however, refers to the vapor formed from water by ebullition. The temperature at which ebullition takes place, or steam is produced, is 212° F., at sea level. The temperature of the formation of steam, however, is influenced by the pressure; it is greater than 212° F. when the pressure exceeds atmospheric pressure at sea level, and less than 212° F. at elevations above sea level where the atmospheric pressure is decreased.

The terms high-pressure steam and low-pressure steam are used more or less relatively, and vary somewhat with respect to the type of boiler used. Ordinary plain cylindrical or flue boilers are usually designed to carry from 60 to 80 lb. of steam, while tubular boilers are designed to carry pressures varying from 80 to 150 lb., or greater. Ordinarily, the term low-pressure steam refers to a steam pressure less than 80 lb. per sq. in., and high-pressure steam to pressures exceeding this amount.

QUES. 1702.—What is the difference between latent and sensible heat? *H.—Ill.*

ANS.—*Latent heat* is the heat absorbed or given out by a body when changing its state. For example, if the temperature of water is raised to 212° F., the increase of temperature up to this point is uniform and

proportional to the amount of heat added. The addition of more heat, however, does not cause any further rise in temperature until the water is wholly converted into steam, when a further addition of heat will again cause a corresponding rise in the temperature of the steam. The heat added during the formation of the steam, or the heat absorbed by the water while changing its state, is called the latent heat of the steam, since its presence is not indicated by any rise in temperature, the temperature of the steam in contact with the water being the same as the temperature of the boiling water.

Sensible heat is any heat causing a rise in temperature; the sensible heat absorbed by a body is indicated by the change that takes place in the temperature of the body. For example, the heat that raises the temperature of water from the freezing point (32° F.) to its boiling point (212° F.) is sensible heat.

QUES. 1703.—Which is hotter, dry or saturated steam? *H.—Ia.*

ANS.—Steam may be both dry and saturated. Hence, this question is not a good one. *Saturated steam* is steam at a temperature and pressure corresponding to its point of condensation; that is to say, it can neither be cooled nor perform work by expanding, without condensing a portion of the steam. Such steam, however, may be perfectly dry. On the other hand, saturated steam may be wet and carry water in suspension. In either case, for the same pressure, the temperature will be the same, that is, saturated steam, whether wet or dry is equally hot. When heat is applied to dry saturated steam under constant pressure, the temperature of the steam will rise and it becomes superheated. Hence, steam that is not saturated, and therefore superheated, is hotter than saturated steam of the same pressure.

QUES. 1704.—Which is the more economical of fuel, high-pressure or low-pressure steam? *H.—Ill.*

ANS.—High-pressure steam results in greater economy in fuel, since it means smaller engines and consequently smaller boilers, and a larger percentage of useful effect obtained from a given weight of steam. The efficiency of steam increases as its pressure is increased, hence the advantage of the use of high-pressure steam.

QUES. 1705.—If a boiler generates steam at 85 pounds pressure, what percentage may be gained by heating the feedwater, originally at 65° F., by means of a feedwater heater to 200° F.? *H.—Ia.*

ANS.—The difference between generating steam from water at 65° F. and water at 200° F. is to be found in the amount of heat consumed in raising the water from 65° F. to 200° F. The temperature of steam at a gauge pressure of 85 lb. per sq. in. at sea level may be found by the formula

$$t = 199 + 14\sqrt{85} = 328° \text{ F.}$$

Considering 1 lb. of water at 32° F., the quantity of heat contained in the steam it will generate at a gauge pressure of 85 lb. per sq. in. at sea level is found by the formula

$$H = 1081.4 + .305 \times 328 = 1{,}181.4$$

The heat required to raise 1 lb. of water from 32° F. to 65° F. is practically $65-32 = 33$ B. T. U.; hence, the heat required to generate 1 lb. of steam at a gauge pressure of 85° F. from feedwater at 65° F. is $1{,}181.4-33 = 1{,}148.4$ B. T. U. The amount of heat saved by heating 1 lb. of feedwater from 65° F. to 200° F. is practically $200-65 = 135$ B. T. U. The percentage of this saving of heat, or the percentage of the saving of fuel, is then

$$\frac{135 \times 100}{1{,}148.4} = 11.75 \text{ per cent.}$$

BOILER DEFINITIONS

Ques. 1706.—What is meant by the water-line, steam space, and the heating surface of a boiler? *H.—Ia.*

Ans.—The *water-line* of a boiler is the surface level of the water in the boiler under normal working conditions. As the water rises and falls, the water-line varies and there may be a low water-line and a high water-line, according to the quantity of water in the boiler.

The *steam space* of a boiler is the volume or space within the boiler, above the water, and occupied by the steam.

The *heating surface* of a boiler is the total surface area of the boiler and flues, exposed directly to the flame and heated gases passing from the furnace to the stack. This includes the entire surface area of the shell and boiler ends enclosed by the brickwork, together with the inner surface of the flues or tubes.

Ques. 1707.—What is priming? *H.—Ia.*

Ans.—Priming in a boiler is the passage of a considerable quantity of suspended water over from the boiler, and is caused by agitation of the water surface in the boiler; this may result from forcing the boiler, or from impurities in the water.

Ques. 1708.—What is the difference between priming and foaming in a boiler and what causes each? *H.—Ia.*

Ans.—What is known as *priming* in a boiler, is very different from foaming. *Foaming* is the bubbling of water caused by the steam as it escapes to the surface. When the boiler primes, the water is carried over with the steam into the cylinder of the engine where it is liable to do much damage. Foaming of the water in the boiler may or may not result in priming.

Priming may result from a number of causes, but is often due to imperfect construction of the boiler, or to a faulty manner of taking the steam from

the boiler, or to carrying too many gauges of water while running. Foaming is usually the result of the presence of grease or other impurities, in the water, which render the escape of the steam up through the water more difficult, the water being lifted by the steam bubbles as they rise. Whatever tends to form a scum on the surface of the water, or to render the molecules of water more cohesive will tend to produce foaming in the boiler.

QUES. 1709.—What are the causes of the water foaming in a boiler? How can foaming be detected in a boiler? *H.—Ia.*

ANS.—Foaming in a boiler is mainly due to the use of impure water, which often produces violent ebullition when steam is generated. The steam generated throughout the water does not escape readily, but carries much of the water with it in its upward passage to the surface, producing bubbles of foam at the surface.

Foaming may be detected by the appearance of water in the gauge-cocks at a higher level than that shown by the gauge glass. The precaution should be taken, however, to ascertain that the glass is not clogged, but is working freely. This will be shown by the free movement of the water when the cocks of the water glass are opened above and below. Foaming may result in, but is not necessarily the cause of, priming.

QUES. 1710.—Define the terms natural draft and forced draft. How is the latter produced?

ANS.—The term *natural draft* refers to the ordinary draft produced by a chimney or stack unaided by any artificial means.

The term *forced draft* refers to a draft produced by means of some auxiliary apparatus, such as a steam jet, or blower introduced into the firebox underneath the grate, or at the bottom of the stack, or a blower or exhaust fan used to increase the draft of the furnace.

QUES. 1711.—What is meant by galvanic action in connection with steam boilers?

ANS.—Galvanic action in this connection refers to the electro-chemical action that is always set up when two metals of different solubility are immersed in the same slightly acid solution. The two metals form at once a voltaic couple with the result that they are more or less rapidly corroded by the chemical action that takes place.

TYPES AND CONSTRUCTION OF BOILERS

QUES. 1712.—What in your opinion is the best kind of boiler for use at a coal mine? Why? *H.—Ia.*

ANS.—Until quite recently, the form of boiler in most common use about coal mines was the ordinary cylindrical boiler or one of the Lancashire type having two large flues running through the length of the boiler. These

forms of boiler seemed best adapted for use at a coal mine, for the reason that they were cheap, simple in construction, easily cleaned, and repaired at small expense, while the item of a saving in fuel was not considered essential. This practice is rapidly changing, however, and modern tubular or water-tube boilers are replacing the older types in many sections of the country, as they are much more economical of fuel.

QUES. 1713.—In what respect is a flue boiler different from a tubular boiler? Which is the more economical, and why? *H.—Ia.*

ANS.—A *flue boiler* differs from a *tubular boiler* only in the size of its flues or tubes; the flue boiler does not usually have more than four or five flues, while a tubular boiler may have a large number of tubes. A tubular boiler provides a greater heating surface for the same boiler capacity. It possesses the disadvantage, however, of being more difficult to clean and to keep in repair. When the feedwater contains much mud or sediment, or produces scale in the boiler, a flue boiler is preferable.

In regard to the relative economy of these two types of boilers, much depends on the intended meaning of this term and the conditions attending the use of the boilers. Under favorable conditions and where fuel is scarce, a tubular boiler will be more economical in the way of producing a larger generation of steam per pound of fuel burned, than the flue boiler; but under other conditions, as with bad water and cheap fuel, a flue boiler will probably prove more economical than a tubular.

QUES. 1714.—What are the chief points in the construction of a good, economical boiler? *H.—Ia.*

ANS.—(1) The boiler should be of sufficient strength to resist the pressure it is designed to carry, which pressure will vary in mining practice from 60 lb. to 100 or 120 lb. per sq. in. The strength of the boiler is very largely affected by the form of joint and style of riveting adopted; by the position and number of its stayrods; and in tubular boilers by the number and position of the tubes and manner of calking the same; by the thickness of the shell or boiler plate. (2) The heating surface of the boiler should be sufficient for the generation of the required quantity of steam. The volume of the steam space above the water in the boiler should be sufficient to avert the danger of priming. (3) The area of the grate should be made proportional to the heating surface, according to the type of boiler and kind of draft employed. (4) The setting of a boiler is an important point aside from its construction. The boiler should be set so as to allow for its expansion and contraction, in order that the brickwork and masonry may not be injured from this cause. The boiler should be set with a slight drainage toward the mud-drum or blow-off at the rear end of the boiler. If this is not done, the accumulation of sediment over the portion of the shell immediately exposed to the fire will cause trouble and be a constant source of danger. (5) The boiler should be provided with an efficient

safety valve, and gauge-cocks, in addition to a glass water gauge. The feedwater should be introduced into the boiler preferably at a point a little below the water-line in the boiler, and steam should be taken from the boiler at a point in the dome where there will be the least danger of priming. (6) Maximum durability, and minimum liability to need of repairs. (7) Easy accessibility of all parts of the boiler, internal and external, for repairs and for removal of scale, mud, dust, and soot.

QUES. 1715.—What thickness of steel plates is required in the shell of a cylindrical boiler 60 inches in diameter, for a safe working pressure of 100 pounds per square inch, the tensile strain on the boiler plate not to exceed 8,000 pounds per square inch, and no allowance to be made for joint? *M.—B. C., Canada*

ANS.—The required thickness of the steel plates in this case is

$$\frac{100 \times 60}{2 \times 8{,}000} = \frac{3}{8} \text{ in.}$$

QUES. 1716.—We have a tank that is full of water in the morning when we commence work, we have no more water in sight, the well is dry, the tank is a circular tank 12 feet in diameter at the top, 14 feet at the bottom, and 18 feet deep. How long will we be able to run, using 1,200 horsepower per hour? *M.—Ill.*

ANS.—The volume of a tank that is shaped like the frustum of a cone is calculated exactly by means of the formula

$$V = \frac{.7854\,h}{3(D-d)}\,(D^3-d^3);$$

in which V = volume of frustum of cone, in cubic feet;
D = diameter of lower base of frustum, in feet;
d = diameter of upper base of frustum, in feet;
h = altitude of frustum or vertical distance between bases, in feet.

Substituting the given values in this formula, the volume of the given tank is

$$V = \frac{.7854 \times 18}{3(14-12)}\,(14^3-12^3) = 2{,}393.899, \text{ say } 2{,}394 \text{ cu. ft.}$$

No data are given to estimate the evaporation of the engine per horsepower per hour, but assuming for an average hoisting engine, in good condition, an evaporation of 35 lb. of water per H. P. per hour, the consumption of water in this case is

$$1{,}200 \times 35 = 42{,}000 \text{ lb. per hr.};$$

or

$$42{,}000 \div 62.5 = 672 \text{ cu. ft. per hr.}$$

Assuming that all the water in the tank can be used for evaporation in the boilers, the length of time the engine will be able to run is

$$2{,}394 \div 672 = 3.56+ \text{ hr., say 3 hr. 30 min.}$$

QUES. 1717.—Give the weight of a boiler 6 feet in diameter, 16 feet long, with sixty-six 4-inch flues, the thickness of steel being $\frac{1}{4}$ inch in the shell and ends of the boiler, and $\frac{1}{8}$ inch in the flues. *M.—Ill.*

ANS.—The amount of steel in the shell is found by multiplying the cylindrical surface by the thickness of the plate; thus,

$$\frac{3.1416\times 6\times 16}{4\times 12} = 6.283+ \text{ cu. ft.}$$

Likewise, for the ends of the boiler, deducting the area cut out at each end by the sixty-six flues,

$$2\times .7854\times[6^2-66\times(\tfrac{1}{3})^2]\times\frac{1}{4\times 12} = .938+ \text{ cu. ft.}$$

For the amount of steel in the flues, multiplying the cylindrical surface of the flues by the thickness of the steel,

$$66\times 3.1416\times(\tfrac{1}{3})\times\frac{16}{8\times 12} = 11.519+ \text{ cu. ft.}$$

Multiplying the sum of these volumes by the weight of 1 cu. ft. of steel (490 lb.), and reducing to tons, the total weight of the boiler is

$$\frac{6.283+.938+11.519}{2{,}000}\times 490 = 4.59+ \text{ T.}$$

QUES. 1718.—What is the horsepower of a horizontal tubular boiler 5 feet in diameter, 18 feet long, containing seventy 3-inch tubes? *H.—Ia.*

ANS.—For a flue boiler, the ratio of the heating surface to the horsepower of the boiler may vary from 8 to 12; assuming this ratio in the present case to be 10, the horsepower of the boiler would be one-tenth of its heating surface. The total cylindrical surface of the boiler shell in this case is

$$18(3.1416\times 5) = 282.744 \text{ sq. ft.}$$

and assuming that two-thirds of this surface is exposed to the flame and heat of the furnace, the cylindrical heating surface of the boiler shell is

$$\tfrac{2}{3}\times 282.744 = 188.5 \text{ sq. ft.}$$

The cylindrical surface of the seventy 3-in. tubes 18 ft. long is

$$70(3.1416\times\tfrac{1}{4})18 = 989.6 \text{ sq. ft.}$$

The area of the two ends of the boiler calculated for a height corresponding to two-thirds of the circumference of the boiler is 31.6 sq. ft. from which must be deducted the double end areas of the seventy tubes, or

$$2\times 70\times .7854\times(\tfrac{1}{4})^2 = 6.87 \text{ sq. ft.}$$

Hence, the entire heating surface of this boiler is

$188.5+989.6+31.6-6.87 = 1{,}202.83$ sq. ft., or approximately 1,200 sq. ft.

The horsepower of the boiler is then $1{,}200\div 10 = 120$ H. P.

BOILER FITTINGS

QUES. 1719.—Name and state the usual appliances and fittings to a boiler as found in the hoisting plant of a mine. *I.—Ia.*

ANS.—The *safety valve* of a boiler is an appliance for preventing a greater pressure in the boiler than the working pressure for which the boiler was designed.

The *water gauge* shows the level of the water in the boiler.

Gauge-cocks or *try-cocks*, usually three in number, placed, one at the water-line, the second about 2 or 3 inches above the first, and the third below the water-line. They are used for the purpose of making an actual test of the level of the water in the boiler and to thus test the accuracy of the water gauge.

A *steam gauge* is an indicator provided with a hand or pointer and a registering dial for the purpose of indicating the steam pressure in the boiler, in pounds per square inch.

The *mud-drum* is a small cylindrical drum placed underneath and at the rear of a boiler to catch the accumulations of sediment deposited from the water in the boiler.

The *blow-off valve* is an ordinary plug valve or cock of large size, at the bottom of the boiler, in the rear, for blowing off and cleaning out the boiler.

The *feed-pump* or *injector* forces feedwater into the boiler.

The *steam separator* dries the steam before it enters the engine cylinder.

The *feedwater heater* heats the feedwater and purifies it before it enters the boiler.

QUES. 1720.—What pipe fittings, valves, and other attachments are used in setting up and connecting a boiler and engine? *H.—Ind.*

ANS.—Steam pipes, blow-off and feedpipes, steam separator, water gauges, and gauge-cocks, safety valve, steam gauge, manhead, globe valve, throttle valve with the necessary sleeve, elbow, tee, and reducing fittings.

QUES. 1721.—What kind of fittings are necessary to make a boiler as safe as possible, as far as the fittings are concerned? *F_2.—Ala.*

ANS.—Every steam boiler should be provided with a safety valve, set to blow off above a certain safe pressure. For stationary boilers, the common lever-and-ball safety valve generally gives the best satisfaction. The boiler should be supplied with a water gauge to show the height of the water in the boiler, and with suitable gauge-cocks for testing the height of the water, and with a pressure gauge connected by a siphon. Most boilers are fitted with a low-water alarm consisting of a fusible plug made of an alloy that readily melts above a certain temperature. The melting of this plug, when the surface of the water has fallen below a certain level, allows the steam to blow into the firebox, giving due warning of the danger, and thereby

avoiding an explosion. Boilers are also supplied with mud-drums for the collection of the sediment in the boiler, and blow-off valves and manholes for the proper cleaning of the boiler, and a feed-pump or injector for forcing water into the boiler. There should be also suitable check valves and a valve at the steam pipe. Other fittings are the feedwater heater, by means of which the water fed into the boiler is first heated to a certain temperature by the exhaust steam of the engine.

QUES. 1722.—What are the necessary safety appliances required for the operation of a boiler?

ANS.—The more important boiler safety fixtures and appliances are, the safety valve that provides for the automatic escape of the steam whenever the pressure in the boiler rises above a fixed point determined by the makers of the boiler. The water gauge is for the purpose of determining the level of the water in the boiler. Besides the water gauge three or more try-cocks, or gauge-cocks, are usually placed in the end of the boiler for the purpose of checking the indications of the gauge by actual trial, to determine whether water or steam is discharged at the height of the cock. Most boilers are now supplied with safety plugs inserted in the crown sheet of the boiler. These plugs are made of fusible metal that will melt and allow the escape of steam from the boiler into the furnace whenever the water in the boiler falls below the height of the plug. The mud-drum, located at the rear end and below the boiler, would hardly be classed as a safety appliance; it is for the purpose of collecting the sediment deposited from the water, and thereby assisting in keeping the boiler free from sediment and scale.

QUES. 1723.—Is a gauge-cock or a water glass to be preferred? Why? *H.—Ia.*

ANS.—The gauge-cock is always more reliable on a boiler than a water glass; and if but one of these is to be employed, the preference should be given to the gauge-cock. The water glass is convenient, but not reliable, and many engineers prefer that it should not be placed on the boiler on account of its often deceptive indications. The reason for this is that the tubes leading from the boiler at either end of the water glass sometimes become stopped, which results at once in the water becoming stationary in the glass, and not indicating the true level of the water in the boiler; or no water may appear in the glass, when there are several gauges in the boiler. In this event, the engineer is absolutely deceived by the indications of the water glass, since he has no means of knowing its condition. This is not the case where gauge-cocks, or try-cocks as they are often called, are used to indicate the height of the water in the boiler. If one of these cocks becomes clogged, it is known at once to the engineer, since either steam or water must always issue when the cock is turned. The cock is then cleaned by inserting a suitable wire.

QUES. 1724.—If you were in charge of a boiler and the glass water gauge should be broken by accident, what would you do? *H.—Ia.*

ANS.—The cocks below and above the glass gauge should be closed as quickly as possible. It is important in doing this to close the lower cock first, as by so doing the engineer will often avoid a serious scalding that may result from closing the upper cock while the lower one remains open. To close these cocks when the glass is broken, the engineer often keeps on hand a long rod with a prong at one end, by which the cock can be reached and turned from a distance.

QUES. 1725.—In trying a gauge-cock, why is it not advisable to jerk the cock open suddenly? *H.—Ia.*

ANS.—In opening a gauge-cock suddenly, a person is liable to receive a drenching of scalding water and steam; the cock should merely be opened sufficiently to ascertain if there is water in the boiler at that level.

QUES. 1726.—In case of imminent danger, supposing that the water had fallen below the water gauge, or the pressure had become dangerously high in a boiler you were in charge of, what would you do?

ANS.—It would increase the danger to attempt to introduce water into the boiler, or to meddle with the safety valve in any way. The fire should be promptly covered or dampened with fresh coal, and the furnace doors allowed to remain open until the pressure in the boiler falls. In case the water is low in the boiler, it will increase the danger to attempt to draw the fire, as the heat will be temporarily increased by so doing. When the boiler is sufficiently cooled, water may be fed into the boiler in the usual manner.

QUES. 1727.—What are the fusible plugs and for what are they used?

ANS.—*Fusible plugs* are usually an alloy of lead, tin, and bismuth in such proportions as to be fusible at a low temperature. Such a plug is forced into a small hole in the crown sheet of a boiler, at a point that marks the low-water level in the boiler. As long as the plug is covered with water it will not melt; but if the water falls below the level of the plug, the heat of the fire quickly melts the plug and the steam blowing into the furnace gives due warning of the danger.

QUES. 1728.—What is the object of a feedwater heater? *H.—Ia.*

ANS.—The first and perhaps principal object of a *feedwater heater* is to economize fuel by saving heat; the feedwater being heated usually from the exhaust steam of the engine and entering the boiler at a temperature very close to its boiling point.

Another important object sometimes attained is the purification of the feedwater. Water carrying carbonic acid will dissolve carbonate of lime; but if this water is heated in a feedwater heater, the carbonic acid is driven

off and the lime precipitated. Sulphate of lime is less soluble in hot than in cold water, hence feedwater containing sulphate of lime is somewhat purified by passing it through a feedwater heater.

QUES. 1729.—What in your opinion is the best place to connect a feedpipe to the boiler? Why? *H.—Ia.*

ANS.—There is some difference of opinion in regard to this matter, but a very common practice is that in which the feedpipe is made to enter the boiler at the front a few inches below the water-line, and in a horizontal position parallel to the axis of the boiler. The pipe should extend into the boiler for a distance of from one-half to two-thirds the length of the boiler, as the temperature of the feedwater approximates more closely to that of the surface water, which is cooler than the water in any other part of the boiler. The water in the boiler is hottest where it comes in contact with the heating surface of the flues or of the boiler shell. Water of a lower temperature should not be injected into the boiler so as to come into immediate contact with these hotter surfaces, as it will cause an unnecessary contraction and expansion of the metal, due to the changing temperature of the water striking against it, and will tend to injure the joints.

QUES. 1730.—Where should the brickwork close in on a boiler? Give reasons. *H.—Ia.*

ANS.—The brickwork should close in to the boiler at a short distance below the low water-line of the boiler, so as to prevent the direct contact of the flame and heated gases of the furnace with the boiler shell above this line. No part of the steam space of a boiler should be exposed to the flame and heated gases of the fire.

QUES. 1731.—What is a blister on a boiler and how is it produced? *H.—Ill.*

ANS.—What is commonly known as a blister in boiler practice is a slight protuberance or swelling produced in a boiler plate or shell by the overheating of the plate when the latter is not sufficiently protected or covered by the water in the boiler.

QUES. 1732.—Are cracks and blisters liable to occur in the best plate iron and steel?

ANS.—Yes, without proper care in firing the boiler and keeping sufficient water therein to prevent the undue heating of the plates, the best steel and iron may be injured in this manner.

QUES. 1733.—What parts of a boiler require strengthening by means of stays? *H.—Ill.*

ANS.—All the flat surfaces of the boiler, and particularly the boiler ends.

SAFETY VALVES

Ques. 1734.—Describe the different kinds of safety valves known to you, and say which one you think is the best, giving the reasons for your choice. *H.—Ill.*

Ans.—The common types of safety valves are the lever valve, the spring-balance valve, and the dead-weight valve. The lever valve, Fig. 1, has a lever *l* suspended above the valve *v* in such manner that the weight of the ball *w* near the end of the lever balances the upward pressure of the steam on the valve, the lever being supported in a horizontal position by the valve stem *p* at a short distance from the fulcrum. The action of the valve is regulated by moving the ball out or in along the lever arm.

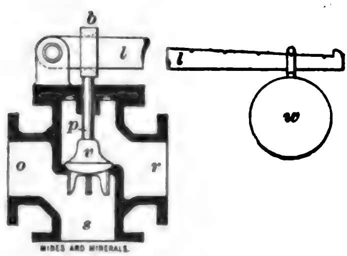


Fig. 1

In the spring-balance valve, the valve is held on its seat by means of a spring supported by a suitable frame above it, the action of the valve being controlled by adjusting the tension of the spring.

In the dead-weight valve, the valve is held on its seat by a weight placed on the end of the valve stem, but these valves are now seldom used. The lever valve is the one most commonly employed for stationary engines, being simple, easily regulated and understood, and requiring little attention. The spring-balance valve is adapted to locomotive boilers or wherever the motion of the boiler would prevent the use of the lever valve.

Ques. 1735.—How far must a weight of 75.375 pounds be placed from the fulcrum of a safety valve having a diameter of 3 inches, the valve stem being 4 inches from the fulcrum, the valve to blow off at 75 pounds pressure? Disregard the weight of the lever and valve. *I.—Ia.*

Ans.—The moment of the total pressure of the steam on the valve *V*, Fig. 2, must be equal to the moment of the weight *P* hanging on the lever at *B*. The moment of a force with respect to a given center or fulcrum is the product obtained by multiplying the force by its distance from the center, measured perpendicular to the direction of the force. Calling the distance of the weight from the fulcrum *x* (inches), we have for the equality of moments, in this case,

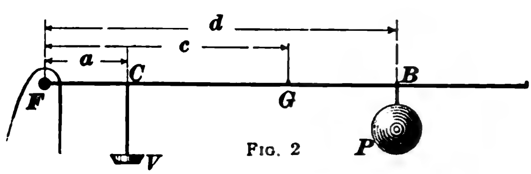


Fig. 2

$$x \times 75.375 = 4 \times 75\ (.7854 \times 3^2);\ x = 28.13$$

QUES. 1736.—The diameter of a safety valve on a colliery boiler is 4 inches; the pressure of steam in the boiler, 65 pounds per square inch; distance of valve stem from fulcrum, 5 inches; total length of lever from fulcrum, 36 inches; weight of lever, 10 pounds; weight of valve, 6 pounds. What weight will be required at end of lever to allow the steam to blow off at this pressure?

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ANS.—The sum of the moments of the weight at the end of the lever and the weight of the lever, must equal the moment of the total steam pressure on the valve less the weight of the valve. Hence, we have, calling the required weight x, and assuming that the lever has a uniform cross-section its entire length, making its center of gravity 18 in. from the fulcrum,

$$36x + (10 \times 18) = 5[65\ (.7854 \times 4^2) - 6]; \ = \ 107.6+ \text{ lb.}$$

QUES. 1737.—How can you prove the correctness of the steam gauge and safety valve on a boiler by comparing them with each other? *H.—Ind.*

ANS.—Place the weight at different points on the lever of the safety valve and raise steam until it blows off, in each position of the weight; then calculate the pressure on the safety valve, in pounds per square inch, and compare with that shown by the steam gauge, in each case. If these agree reasonably close, it is probable that both the safety valve and the steam gauge are working properly.

EXPANSION

QUES. 1738.—What causes expansion? In what direction is it greatest? Give reason for your answer. *H.—Ia.*

ANS.—*Expansion* is an increase in volume without any increase in mass. In solids and liquids, it is usually the direct result of the application of heat. When heat is applied to a body, its temperature is raised, and its molecules are thereby thrown into more rapid and extended vibrations, separating them farther from each other, and resulting in the expansion or increase in size of the body.

Cubical expansion of a body takes place in all directions, but the extension is greatest in the direction of the greatest dimension. The lineal expansion of a boiler or of a rod is more apparent, therefore, than the expansion in its cross-section, or the enlargement of its volume.

The expansion of a gas is an increase in its volume and may be due to a decrease in the pressure that it supports, or to an increase in its temperature.

QUES. 1739.—What do you mean by expansion? What causes the expansion of a boiler? In what direction is it greatest—

through the length or the diameter of a boiler? Give reasons for your answer. *H.—Ind.*

Ans.—Increase of size without increase of mass. Heat and the pressure of the steam in the boiler both tend to separate the molecules and thus increase the size of the boiler.

Lengthwise, as there is a greater body of metal to expand in that direction.

Ques. 1740.—In setting a steam boiler, what is the result if the proper allowance is not made for contraction and expansion? *H.—Ia.*

Ans.—The cracking or tearing apart of the walls, or breaking of the rods or other supports, probably followed by the settlement of the boiler out of position, thereby bringing an undue strain on the boiler itself, and possibly opening the joints between the plates causing a leakage of steam or water or both.

Ques. 1741.—What are the effects of unequal expansion and contraction in a boiler? *H.—Ia.*

Ans.—When the different parts of a boiler expand or contract unequally, they change their relative positions with respect to each other; the shape and form of the several parts change unequally and as a result they are not fitted to each other, and an undue strain is thus caused in all the rivets, bolts, and stays joining and supporting these parts. The direct and manifest result of unequal expansion and contraction is the opening of seams between the boiler plates and the buckling or warping of the plates, thus rendering the boiler unsafe.

Ques. 1742.—How would you set a boiler so as to allow all its parts to be free to move under a change of temperature? *H.—Ia.*

Ans.—A steam boiler should be supported by angle castings riveted to the sides of the boiler and resting on wall plates, on which they may slide, or it may be hung, in part, from above by rods fastened to iron bands passing around the boiler, or fastened to the usual lugs.

BOILER FIRING

Ques. 1743.—How would you fire steam boilers to get the best results from them and from the fuel used? *H.—Ill.*

Ans.—The firing of the boiler should be performed in as uniform a manner as possible, and at regular short intervals. The coal should be evenly spread over the surface of the fire, in a thin layer, so as not to reduce the heat of the fire or render the same irregular. The greatest efficiency of a fuel is

produced when there is an even combustion over the entire surface of the grate. The thickness of the bed of fuel should not be so great as to prevent the admission of the air, nor so thin as to allow the upward passage of cold air through the grate. Care should be taken not to cool off the fire-bed unnecessarily while firing.

QUES. 1744.—What are the special dangers and disadvantages attending the excessive firing of steam boilers? *H.—Ia.*

ANS.—Excessive firing of a boiler is bad for several reasons; it is wasteful of fuel, generating less steam per pound of fuel burned. The forced draft often produces an overheating of the fire-plates or crown sheets of the boiler and may result in burning or blistering the boiler. Excessive firing tends to produce a spheroidal state of the water in contact with the crown sheets of the boiler, and may, at times, cause an explosion by the overheating of the plates at this point due to this condition of the water, the water being converted instantly into steam when it is finally brought in contact with the overheated plates. This contention, however, though held by many engineers, is not fully substantiated by experiment.

QUES. 1745.—How many gauges of water would you consider it safe to leave in a boiler after banking the fire for the night? *H.—Ia.*

ANS.—When banking the fire under the boiler for the night, or for any length of time, it is usually advisable to leave the boiler well filled, that is, to have 2½ or 3 gauges of water. By doing this, there will be no danger of the water running low before morning should the fire start up somewhat. and there will be a good body of hot water for a start in the morning.

INCRUSTATION AND SCALE

QUES. 1746.—What is there in water that produces incrustation? *H.—Ia.*

ANS.—The causes of incrustation are the deposition and hardening of suspended matter from the water; and the deposition of salts held in solution in the water and thrown down by boiling, or by the evaporation of the water. The carbonates of lime and magnesia are deposited by boiling, which drives off the carbonic acid that holds them in solution. Sulphate of lime is deposited, because sulphate of lime is soluble in cold water, less soluble in hot water, and insoluble above 270° F. Magnesia is deposited because magnesium salts decompose at high temperatures. Lime soap, iron soap, etc. are formed by the saponification of grease and deposited.

QUES. 1747.—What kind of incrustation does the most harm to the boiler, and in what manner may it cause an explosion? *H.—Ia.*

Ans.—All manner of incrustations in boilers are harmful, and should be prevented as far as possible or removed as they form. Some incrustations are harder than others and more difficult to detach from the boiler shell; these perhaps are the more dangerous class of incrustations, because they allow the plates to become very much overheated and perhaps blistered and ruined. The manner in which incrustations act to cause an explosion is as follows: The incrustation not being a good conductor of heat destroys the efficiency of the boiler, or its capacity to produce steam. To overcome this defect, the fire is urged too strongly, and the parts of the boiler exposed to the fire become very much overheated and bulge or blister. The plates expand more quickly than the incrustation lining them, which may result in cracking the incrustation, thus suddenly permitting the water to come in contact with the red-hot plate, resulting in the sudden formation of a large amount of steam, and an explosion is the result.

Ques. 1748.—How can the bad effects of scaling be prevented? *H.—Ill.*

Ans.—The bad effects of scaling are best avoided by preventing the formation of scale, or by its removal at regular intervals as it is formed. The several means of preventing incrustation are: (1) Filtration of the water. (2) Frequent blowing-off of the surface to remove the light particles and scum floating on the surface of the water; and regular blowing off of the entire boiler at such periods as experience shows to be necessary in each case. (3) Maintaining a thorough circulation in the boiler. (4) Heating the feedwater. (5) Chemical treatment of the water in the boiler, or the introduction of a suitable amount of kerosene oil into the feedwater. (6) Chemical treatment of the feedwater outside of the boiler when advisable. (7) Galvanic action produced by hanging sheets of zinc in the water inside the boiler. The methods employed for the removal of boiler scale are explained in answer to Ques. 1750.

Ques. 1749.—Why should scale never be allowed to accumulate in a boiler? *H.—Ia.*

Ans.—The accumulation of scale in any part of the boiler destroys the heating capacity of the boiler, thus increasing the fuel consumption per horsepower per hour. An accumulation of scale on the crown sheets of the boiler and on the flues exposed to the direct action of the flame obstructs the passage of the heat from the fire to the water, and there is a danger of overfiring the boiler. When scale is formed, the metal exposed to the direct action of the flame becomes overheated, and as a result blisters are formed on the surface of the metal. When this occurs, the metal may become red hot, and there is danger of the scale cracking and allowing the water to come suddenly in contact with the red-hot metal, causing an explosion.

CLEANING A BOILER

Ques. 1750.—How would you proceed to clean a boiler? *H.—Ill.*

Ans.—A common practice in reference to the cleaning of boilers at collieries is to blow off the boiler under steam either wholly or in part. In the former case, the fire is first drawn before the blow-off valve is opened; this should not be done when the fire is too hot. In the latter case, when the boiler is blown off in part, care should be taken that there is plenty of water in the boiler before opening the blow-off valve, and this should not be done under too high a pressure. To avoid the too sudden contraction of the boiler plates, the pressure should be allowed to fall to 15 or 20 lb. before blowing off in this manner. The blow-off valve should remain open only a moment, and be closed again before the water level falls low enough to expose the tubes, crown sheet, or fire-plates of the boiler. This method of blowing off the boiler is not to be recommended, however. Blowing off in part can only effect the removal of a small amount of sediment that has accumulated over the blow-off orifice, the larger part of the sediment in the boiler is held in suspension in the water when under steam. When the boiler is wholly blown off, the incrustation or caked sediment is dried quickly by the heat of the boiler, and rendered much harder and more difficult to remove.

The better plan for cleaning a boiler is to throw the boiler out of service at regular intervals or periods, and allow it to cool, after drawing the fire. When the boiler is cold, the blow-off valve is opened to drain the water from the boiler, the safety valve being lifted at the same time to permit the entrance of air. The manholes are then opened and the boiler entered and washed out thoroughly. Any adhering cake or incrustation must be loosened with the hammer and scraper. A short length of chain with a hand ring at each end can often be used to advantage in removing the scale from the tubes. The chain is passed once or twice around the tube, and worked backwards and forwards to scrape off the adhering scale. Care should be taken not to injure the plates of the boiler when using the scraper, and all the joints, rivets, and bolts should be examined as the work proceeds to detect any possible signs of weakness. When the scale has become very hard, it may often be softened by the addition to the water in the boiler of ¼ lb. of caustic soda per horsepower and steaming for a few hours.

CARE OF BOILERS

Ques. 1751.—What has to be most carefully observed in caring for boilers? *M.—Ill.*

Ans.—The thorough cleansing of the boiler at regular intervals and the removal of any incrustation that may have formed. The feedwater

supply to the boiler should be as free as possible from earthy impurities that will precipitate on boiling, or acids that will corrode and weaken the boiler. It is important that the crown sheets of a boiler exposed to the direct action of the fire should be carefully inspected each day. The water level should be carefully watched while the boiler is under steam and maintained a safe distance above the fire-line of the boiler. The gauge-cocks should be used to ascertain the height of the water level.

QUES. 1752.—What care should be taken of steam boilers to secure the best results from their use? *H.—Ia.*

ANS.—It is important that a steam boiler should be carefully examined at regular intervals, depending on the conditions under which the boiler is used. A boiler in constant use should be inspected daily, especially if the demands on the boiler are heavy. It should be blown off and cleaned at regular and stated intervals. In general, it is not sufficient to depend on the partial blowing off of the boiler, which is the practice very often employed where a boiler is in steady use. By this method, a portion only of the sediment and very little, if any, of the accumulating scale are removed. The feedwater of the boiler should be as pure as possible, and should be heated before being introduced into the boiler. This is generally accomplished by means of a feedwater heater, which is a receptacle for holding the water to be used in the boiler and through which all or part of the exhaust steam of the engine is passed before it is allowed to escape into the air. By this means, the temperature of the boiler is kept more uniform and heat and fuel are economized. Water should be fed into the boiler in small quantities at regular intervals, and the water level should not be allowed to fall so low that water will not appear in the lower gauge-cock when this is opened. The glass water gauge should be tested at frequent intervals by opening the gauge-cocks, to ascertain that the glass gauge is not clogged, which frequently happens when impure water is being used in the boiler. Care is also required in the firing of a boiler to insure a uniform and even heating of the boiler plates exposed to the fire. Forcing a boiler by injudiciously urging the fire may result in injury to the boiler. A careful watch should be kept of all the boiler fittings and appliances for indicating the steam pressure and the water level. The safety valve and steam gauge in particular should be examined from time to time and compared to ascertain that they are in good working order.

QUES. 1753. In making an examination of a cylinder boiler, to what parts would you give special attention? *H.—Ia.*

ANS.—Special attention should be given to the joints and to those parts of the boiler where the plates are exposed to the immediate action of the fire, especially where the tubes are calked or join the boiler ends. Special care should be taken in the examination of all the riveted joints of the boiler and points where stayrods are made fast to the boiler plates or shell. The various connections and boiler fittings should be likewise carefully examined. Throughout the examination, particular attention should be

given to stayrods, rivets, and plates, to detect the first signs of corrosion, which will quickly weaken the boiler if allowed to proceed.

QUES. 1754.—What part of a boiler is apt to weaken soonest? *H.—Ill.*

ANS.—That portion of the boiler that is directly exposed to the fire; owing to the severity of the heat of the fire, and the tendency of the iron to blister. Other weak portions of the boiler are the points where the stayrods are bolted to the shell, or where boiler plates are riveted together, since corrosion is more apt to take place at these points. A manhole or any opening cut in the boiler for steam or water connections, or for the steam dome, forms a weak point, because material has been cut from the shell, leaving it more or less unsupported at such point.

QUES. 1755.—How may radiation from boiler, pipes, and engine cylinders be prevented? *H.—Ia.*

ANS.—By suitably covering the boiler, pipes, and cylinders with asbestos wool, felt, or other good non-conducting material, much of the heat lost by radiation may be saved.

TESTING A BOILER

QUES. 1756.—How would you proceed to make a test examination of a boiler as to its safety under a given working pressure? *H.—Ill.*

ANS.—The boiler should be tested, when cold, by a hydrostatic pressure varying from 1½ to 2 times the working pressure desired. When under this pressure, the various joints and openings of the boiler should be carefully inspected to detect any signs of the leakage of water, or any weakness in the parts of the boiler. The pressure should be applied slowly and gradually until the maximum pressure is reached, and this maximum pressure should be maintained a sufficient length of time to allow of the thorough inspection of the boiler and to insure the ability of the boiler to withstand such a pressure. The strength of a boiler is always less when under steam than when cold, and for this reason the hydrostatic pressure to which the boiler should be tested is always much greater than the working pressure desired.

QUES. 1757.—A boiler is to be run under a pressure of 100 pounds to the square inch; to what hydrostatic pressure ought it be tested for safety? *H.—Ill.*

ANS.—To insure safety under a working pressure of 100 lb. per sq. in., a boiler should be tested to 1½ or 2 times this pressure, or 150 to 200 lb. per sq. in. Practice varies in this regard; in many cases, the rules and

regulations of Boards of Inspectors, or of the Navy Department of the United States, specify the hydrostatic pressure to which certain classes of boilers shall be tested. In other cases, this is left wholly to the judgment of the engineer or party in charge.

QUES. 1758.—How would you test the braces in a boiler? *H.—Ill.*

ANS.—The braces on the interior of a boiler should be tested by striking them with a hammer to see that they are tight and in good condition. When struck, a good brace should give out a clear, ringing sound and should appear firm. The ends, or eyes, of the brace should be carefully inspected to see that they are not corroded sufficiently to require replacing.

LEGAL REQUIREMENTS FOR BOILERS

QUES. 1759.—Under what conditions can steam boilers and ventilating fans be placed inside bituminous mines? *I.—Pa. (B)*

ANS.—The Bituminous Mine Law of Pennsylvania requires steam boilers underground to be placed within 50 ft. of the foot of an upcast shaft, which has an area of at least 25 sq. ft. The main or principal ventilating fan of a mine can only be placed below the ground when no explosive gas has been detected in the mine, and the air is not contaminated with coal dust.

QUES. 1760.—What is the law in reference to boilers and boiler houses? *H.—Ill.*

ANS.—Section 4 of the Mining Law of Illinois reads in part as follows:

(*a*) *Location.*—Any building erected after the passage of this act, for the purpose of housing the hoisting engine or boilers at any shaft, shall be substantially fireproof, and no boiler house shall be nearer than 60 feet to the main shaft or opening or to any building or inflammable structure connecting therewith.

(*g*) *Gauges.*—Every boiler shall be provided with a steam gauge, except where two or more boilers are equipped and connected with a steam drum, properly connected with the boilers to indicate the steam pressure; and another steam gauge shall be attached to the steam pipe in the engine house, the two to be placed in such positions that both the engineer and fireman can readily see what pressure is being carried. Such steam gauges shall be kept in good order and adjusted and be tested as often at least as every 6 months.

(*h*) *Safety Valves.*—Every boiler or battery of boilers shall be provided with a safety valve of sufficient area for the escape of steam, and with weights and springs properly adjusted.

(*i*) *Inspection of Boilers.*—All boilers used in generating steam in and about coal mines shall be kept in good order, and the operator of every coal mine where steam boilers are in use shall have said boilers thoroughly examined and inspected by a competent boilermaker or other qualified person not an employe of said operator, as often as once in every six months, and oftener if the inspector shall deem it necessary, and the result of every such inspection shall be reported on suitable blanks to said inspector.

CHAPTER XX

STEAM ENGINES

GENERAL DEFINITIONS

QUES. 1800.—Name and define some of the principal terms used by hoisting and slope engineers. *H.—Ia.*

ANS.—Among the numerous terms used by stationary engineers and to which this question might refer, the following are the most common: (1) *Horsepower* (H. P.) is the power by which engines are rated, being the power required to raise 33,000 lb. through a vertical height of 1 ft., in 1 min. of time. (2) *Indicated horsepower* (I. H. P.) is the horsepower of an engine as calculated from a card taken from an indicator on the engine. (3) *Mean effective pressure* (M. E. P.) is sometimes described as the *average* pressure of steam per square inch, in the cylinder, throughout a single stroke of the piston; it is the pressure that multiplied into the cylinder displacement per minute gives the foot-pounds of work per minute or the power of the engine. (4) *Initial pressure* is the steam pressure in the cylinder, before the valve starts to cut off the supply of steam. (5) *Terminal pressure* is the steam cylinder pressure near the end of the stroke, after expansion has taken place and before exhaust commences; it is the steam cylinder pressure at the moment of release. (6) *Back pressure*, when the engine exhausts into the atmosphere, is the pressure on the exhaust side of the piston due to the resistance of the exhaust ports; for a condensing engine the back pressure is indicated by the vacuum gauge on the condenser. A large number of other like terms might also be given.

QUES. 1801.—What is meant by clearance in the cylinder of an engine? *H.—Ill.*

ANS.—The term clearance in relation to a cylinder may have two meanings. It may refer simply to the actual distance between the piston and the cylinder head when the former is at the end of its stroke, which is more properly *clearance distance*. The more usual meaning of the term, however, is the volume of space between the end of cylinder and the piston at the end of its stroke, together with the volume of the steam ports as far as the face of the valve; this is known as *clearance volume* and is explained as the ratio that the volume of the steam space in the cylinder and the steam port up

to the valve when the piston is at the end of its stroke, bears to the volume of the steam space in the cylinder and port on the same side of the piston when the latter is at the beginning of its stroke.

QUES. 1802.—What is compression, in engine practice, and what is its object? *H.—Ia.*

ANS.—Compression, in engine practice, relates to the compression of the steam remaining in the cylinder when the exhaust port closes just previous to the end of the stroke, the steam being then compressed between the piston, as it moves forwards, and the cylinder head. The object of compression is to overcome the inertia of the piston by the cushioning of the steam, thus gradually reducing the pressure on the crankpin and assisting to start the piston on its return stroke; all of which are important points to be accomplished.

QUES. 1803.—What gain is effected by using high-pressure steam expansively rather than low-pressure steam full stroke? *H.—Ill.*

ANS.—There is a saving in the quantity of steam required per horse-power per hour. The steam enters the cylinder at practically the boiler pressure, and remains at this pressure, up to the point of cut-off, after which the work, during the remainder of the stroke, is performed by the expansion of the steam in the cylinder. An early cut-off allows the steam to expand and hence more work is obtained from the same amount of steam. In a simple duplex engine, using steam at a fairly high pressure, an earlier cut-off than would be employed in a compound engine would be advisable. If the steam pressure is very high, however, too much expansion, caused by too early a cut-off, will cause the cylinder to cool too much and will prove a disadvantage. By the expansion of the steam, the temperature and pressure of the exhaust is reduced and a smaller number of heat units are lost. The high steam pressure is also better adapted to hoisting, since it increases the lifting power of the engine, and enables the engineer to start the load off the bottom more readily, whatever the position of the engines. In the use of low-pressure engines using steam at full stroke, the lifting power would often prove to be inadequate for this purpose.

QUES. 1804.—What is the purpose of a flywheel on an engine? What is the effect if the flywheel is too light for its work? If it is too heavy? *H.—Ind.*

ANS.—The purpose of a flywheel is to carry the engine over the center, and to steady it in running, by taking up power in the middle of the stroke and giving it out at the end of the stroke.

If the flywheel is too light, the engine will not run uniformly and under a heavy load may fail to carry over the dead center.

If it is too heavy, too much power will be required to start the engine, and after it has got under headway it will be difficult to stop, resulting in a loss of power.

QUES. 1805.—What is an eccentric? *H.—Ia.*

ANS.—The eccentric of an engine is a disk having a groove cut in its circumference for holding a band that encircles the disk and to which is attached the eccentric rod that operates the valve of the engine. In this disk a hole is bored, the center of the hole being at a distance from the center of the disk equal to one-half the throw of the valve; the diameter of the hole is such as to cause the eccentric to fit tightly on the shaft of the engine, to which it is keyed in the usual manner.

QUES. 1806.—For what purpose are bearings bushed? What metals are generally used for this purpose, and why? *H.—Ia.*

ANS.—Bearings are subject to wear, and are often bushed or lined with a metal that wears more slowly. The prime object of bushing, however, is to reduce the friction and overheating of the bearing by the use of an antifriction metal. Gun bronze, Babbitt metal, or other soft white alloy is very commonly used for this purpose. Many of these metals do not reduce the friction over that of ordinary brass, but reduce the tendency to the overheating of the bearing. When a bushing wears, it can be removed and a new one substituted more cheaply than if the whole bearing has to be replaced.

TYPES OF ENGINES

QUES. 1807.—What are the advantages of a double over a single hoisting engine? *H.—Ind*

ANS.—It can be run more steadily, and as the cranks are set at right angles there is no danger of its stopping on the dead center.

QUES. 1808.—Why is a geared engine preferred to one coupled direct, at the mines of Indiana? *H.—Ind.*

ANS.—It allows the engine to run faster with the same speed at the drum, gives better control of the engine in a shallow shaft, and at the same time allows the use of a larger drum, which is easier on the ropes.

QUES. 1809.—What is the difference between a condensing and a non-condensing engine? *H.—Ia.*

ANS.—A condensing engine is one in which the exhaust steam of the cylinder is discharged into a chamber where it is condensed, thereby creating a partial vacuum in the chamber and decreasing the back pressure due to the atmosphere, and increasing the effective power of the engine. In a non-condensing engine, on the other hand, the exhaust steam is discharged into the atmosphere, and the back pressure on the piston is then the pressure due to the resistance of the steam ports, plus the pressure of the atmosphere.

STEAM PRESSURES

QUES. 1810.—What is piston displacement? How is it measured? *H.—Ia.*

ANS.—Theoretically, the term *piston displacement* describes the volume of a cylinder whose base has an area equal to the area of the piston, and whose height is equal to the distance through which the piston moves in a given time. For a single stroke, the height of this theoretical cylinder would be equal to the length of the stroke of the piston; for a minute of time, the height of the theoretical cylinder would be equal to the piston speed expressed in feet per minute.

The piston displacement of an engine, for a single stroke, is measured by multiplying the sectional area of the piston, in square inches, by the length of the stroke, in inches, and dividing the product by 1,728; the quotient obtained will be the piston displacement for one stroke expressed in cubic feet. Multiplying the sectional area of the piston, in square inches, by the piston speed of the engine, in feet per minute, and dividing the product by 144 will give the piston displacement expressed in cubic feet per minute. For example, the piston displacement of a 12″×16″ engine running at a speed of 600 ft. per min. will be

$$\frac{(.7854 \times 12^2)\ 16}{1{,}728} = 1.047+ \text{ cu. ft.}$$

for a single stroke, or

$$\frac{(.7854 \times 12^2)\ 600}{144} = 471.24 \text{ cu. ft. per min.}$$

QUES. 1811.—An engine cylinder is 12 inches in diameter and 18 inches long; what is its sectional area? Find the cubical contents of this cylinder. *H.—Ia.*

ANS.—The sectional area of this cylinder, or the area of its piston is $.7854 \times 12^2 = 113.09+$ sq. in. The cubical contents of the cylinder is $113.09 \times 18 = 2{,}035.62$ cu. in.

QUES. 1812.—Define the term forward pressure. *H.—Ia.*

ANS.—The forward pressure in a steam cylinder is the live steam pressure that drives the piston forwards.

QUES. 1813.—What is back pressure? *H.—Ia.*

ANS.—In steam-engine practice, the term back pressure relates to the pressure opposing the forward motion of the piston and caused by the resistance of the valves and exhaust passages. In non-condensing engines, the back pressure is generally measured from the atmospheric line, but in condensing engines it is measured from the vacuum line.

QUES. 1814.—What is mean effective pressure? *H.—Ia.*

ANS.—The expression mean effective pressure, with respect to a steam engine, is the average steam pressure in the cylinder estimated on a basis of uniform work performed throughout the length of the stroke. That is to say, it is such a pressure, in pounds per square inch, as would produce the same work in the cylinder if maintained uniformly throughout the length of the stroke, as is actually produced in a single stroke of the engine by the steam when allowed to expand in the cylinder for a portion of the stroke.

QUES. 1815.—What is the difference between pressure above the atmosphere and pressure above a vacuum? *H.—Ia.*

ANS.—The pressure above the atmosphere is simply gauge pressure, while the pressure above a vacuum is the sum of the gauge pressure and the atmospheric pressure; the latter is therefore always greater than the former by an amount equal to the atmospheric pressure.

QUES. 1816.—The total pressure on a steam piston is 100 short tons; if the diameter of this piston is 24 inches, what is the pressure of steam per square inch? *I.—Pa. (A)*

ANS.—The area of the piston is $.7854 \times 24^2 = 452.39+$ sq. in. The pressure per square inch is then

$$\frac{100 \times 2{,}000}{452.39} = 442+ \text{ lb.}$$

QUES. 1817.—The diameter of the piston of an engine is 22 inches; find the total pressure on the crank-shaft; the crank makes an angle of 60° with the axis of the cylinder, and the steam pressure on the piston is 65 pounds per square inch. Tan 60°, 1.73205; cotan 60°, .57735; sin 60°, .86603; cos 60°, .5. *I.—Ia.*

ANS.—Calling the total cylinder pressure P,

$$P = 65\ (.7854 \times 22^2) = 24{,}708+ \text{ lb.}$$

Assuming a long connecting-rod transmitting a practically horizontal force to the crankpin, equal to the total cylinder pressure, and resolving this into two forces, one a tangential force producing rotation, the other a radial force producing pressure on the crank-shaft, the latter force is

$$F = 24{,}708 \times \cos 60° = 24{,}708 \times .5 = 12{,}354 \text{ lb.}$$

QUES. 1818.—We wish to put in a pair of compound engines at a mine; we are working under a boiler pressure of 150 pounds per square inch; the high-pressure cylinder is 24 in. × 32 in.; what size cylinder should be used for the low-pressure cylinder? *M.—Ill.*

ANS.—It is common practice to design a compound condensing engine for a terminal pressure varying from 6 to 10 lb. For two-cylinder compounds, the total number of expansions in the high- and low-pressure cylinders

is found by dividing the initial absolute pressure by the terminal absolute pressure; the ratio of the volumes of the two cylinders is then equal to the square root of the total number of expansions, assuming that there is no drop or loss of pressure between the cylinders. For a boiler pressure of 150 lb., we may assume an initial pressure in the first cylinder of 145 lb., making the initial absolute pressure $145+15 = 160$ lb. The absolute terminal pressure being, say 8 lb., the total number of expansions is $160 \div 8 = 20$, and the cylinder ratio is therefore $\sqrt{20} = 4.47$. Or, since the diameter ratio is equal to the square root of the cylinder ratio, the former is $\sqrt{4.47} = 2.11$; that is to say, the diameter of the low-pressure cylinder, in this case, may be 2.11 times the diameter of the high-pressure cylinder, or 24×2.11 = say 50 in., making the size of the low-pressure cylinder 50 in. × 32 in.

PISTON SPEED

QUES. 1819.—(*a*) What are the advantages of high piston speed? (*b*) What are the disadvantages of high piston speed? *H.—Ia.*

ANS.—(*a*) A smaller and lighter engine for the same power, less difficulty of lubrication, smooth running. (*b*) Much will depend on the purpose for which the engine is designed, and only in a general way can it be stated that there is an increased wear and tear due to a high piston speed; the large per cent. of clearance spaces causes a loss in steam consumption not always counterbalanced by the gain in less radiation.

QUES. 1820.—What are the effects of high piston speed on the rod packing? *H.—Ia.*

ANS.—High piston speeds increase the wear of the packing.

QUES. 1821.—An engine has a piston speed of 300 feet per minute when running at a speed of 100 revolutions per minute; if the ratio of the diameter of the cylinder to the length of stroke is 1 : 1.5, what is the size of the engine? *H.—Ia.*

ANS.—An engine makes two strokes every revolution; the number of strokes per minute in this case is therefore $2 \times 100 = 200$. The piston speed being 300 ft. per min., the length of the stroke of the engine is then $300 \div 200 = 1.5$ ft. The ratio of the diameter of the cylinder to the length of stroke being 1 : 1.5, the diameter of the cylinder in this case is 1 ft. The size of the engine is then 12 in. × 18 in.

QUES. 1822.—If the length of stroke of an engine is 2.5 feet and the piston speed 900 feet per minute, what is the number of revolutions? *H.—Ia.*

ANS.—Since the engine makes two strokes during each revolution, the number of revolutions is equal to the piston speed in feet per minute, divided by twice the length of the stroke. Then

$$N = \frac{900}{2 \times 2.5} = 180 \text{ rev. per min.}$$

QUES. 1823.—A pair of hoisting engines have cylinders 30 inches in diameter and a 60-inch stroke, the steam pressure is 90 pounds per square inch. How many revolutions per minute will they be running when generating 1,000 horsepower? *I.—Ill.*

ANS.—Reducing the horsepower to foot-pounds per minute, and dividing by the total pressure on the two pistons, and by the length of the piston travel per revolution, the speed of the engine is

$$\frac{1{,}000 \times 33{,}000}{90 \times 2\ (.7854 \times 30^2) \times 2 \times 5} = 25.9 \text{ rev. per min.}$$

26 rev. would be used in calculations.

QUES. 1824.—The flywheel of an engine is 6 feet in diameter and makes 60 revolutions per minute. It drives a 4-foot pulley on the main shaft. A 12-inch pulley on the main shaft drives a 15-inch pulley on the countershaft. A 12-inch pulley on the countershaft drives a 9-inch pulley on a shaft on which is a pinion that meshes into a large gear having 51 teeth, and attached to the face plate of a lathe. How many teeth must the pinion have in order that the face plate may make 32 revolutions per minute? *I.—Ia.*

ANS.—The ratio between the speeds, in revolutions per minute, is always equal to the inverse ratio between the diameters; then if x represents the required speed, in revolutions per minute, the speed in each is as follows:

Speed of main shaft, $\frac{x}{60} = \frac{6}{4}$, and $x = 90$ rev. per min.;

Speed of countershaft, $\frac{x}{90} = \frac{12}{15}$, and $x = 72$ rev. per min.;

Speed of pinion shaft, $\frac{x}{72} = \frac{12}{9}$, and $x = 96$ rev. per min.

In the same manner as before, the speed ratio in revolutions per minute is always equal to the inverse ratio of the number of teeth in the respective gears. If x is the number of teeth required in the pinion when making 96 rev. per min. to drive a gear-wheel having 51 teeth at a speed of 32 rev. per min.,

$$\frac{x}{51} = \frac{32}{96}, \text{ and } x = 17 \text{ teeth}$$

QUES. 1825.—The piston speed of an engine is 540 feet per minute, the number of revolutions per minute 150; what is the length of stroke? *H.—Ia.*

Ans.—Since there are two strokes to every revolution of the engine, the length of stroke is

$$\frac{540}{2\times 150} = 1.8 \text{ ft.} = 1 \text{ ft. } 9\tfrac{5}{8} \text{ in.}$$

REVERSING GEARS

Ques. 1826.—Describe the action of the reversing gear of a hoisting engine. *H.—Ind.*

Ans.—Throwing the reverse lever raises the block in the link and causes the valve rod to travel in the opposite direction from that in which it was traveling when the block was at the bottom of the link, and the steam is admitted to the opposite end of the cylinder at the corresponding point of the stroke, causing the engine to run in the opposite direction.

Ques. 1827.—What is a link motion, and what is its purpose? *H.—Ia.*

Ans.—A link motion is an arrangement of levers and lever arms that will provide both a forward and a backward motion of a valve corresponding to the forward motion of the eccentric or engine. Its purpose is to enable the engineer to reverse the engine, running it in either direction as desired.

Ques. 1828.—What is the object in curving the links of a Stephenson link motion? Would it be necessary to make them straight for a hoisting engine, and why?

Ans.—The object in curving the links is to equalize the travel of the valve on each side of the center.

While many would say that the reversing links of a hoisting engine should be curved, and while this is usual in mining practice, there are some who rightly contend that if the valve gear is properly designed, a straight link will suit the purpose as well as a curved link in hoisting engines. Briefly stated, the straight-link Stephenson gear is adapted to conditions where the link is used for the purpose of reversing the engine only, or, where the engine is always run with the link in full gear. The curved link on the other hand, enables the reversing gear to be used for the purpose of adapting the cut-off to a variable load. In the case of hoisting engines, except at very deep shafts, the variable load is almost universally compensated by a proper use of the throttle, rather than by altering the position of the link, and in such case the straight link of the Stephenson gear may be used. The emergency may, and occasionally does, arise, however, when it is necessary to throw a hoisting engine on center while under a full head of steam, and the curved link is best adapted to meet this condition, as well as to alter the cut-off to suit the variable load in deep hoisting.

Ques. 1829.—What is meant by the slip in the link of an engine?

Ans.—This term relates to the unsteady movement of the block in the link due to the vibratory movement of the rocker-arm. Slip causes an unnecessary amount of wear of the link and block.

HORSEPOWER OF ENGINE

Ques. 1830.—What are the elements absolutely required in order to calculate the horsepower of an engine? *H.—Ia.*

Ans.—It is necessary to know the mean effective pressure, M. E. P. (pounds per square inch), of the steam in the cylinder; the length of stroke of the piston (feet); the sectional area of the cylinder (square inches), and the number of strokes or number of revolutions made by the engine in a minute. The continued product of these factors divided by 33,000 will give the indicated horsepower of the engine.

Ques. 1831.—How is the horsepower of an engine determined? *H.—Ia.*

Ans.—The theoretical horsepower of a simple engine is usually calculated by estimating the power developed in one cylinder only, whether the engine be single or duplex. The usual formula used for this purpose is as follows:

Let H = the horsepower developed;
p = the mean effective cylinder pressure, in pounds per square inch;
l = length of stroke, in feet;
a = the sectional area of the steam cylinder or piston, in square inches;
n = number of strokes per minute.

Then,
$$H = \frac{plan}{33{,}000}$$

Ques. 1832.—The area of the piston of an engine is 500 square inches, the mean effective pressure 30 pounds per square inch, length of stroke 8 feet, and the engine is making 20 strokes per minute; calculate the horsepower developed. *I.—Ia.*

Ans.—Substituting the given values in the formula for horsepower, we have

$$H = \frac{plan}{33{,}000} = \frac{30\times 8\times 500\times 20}{33{,}000} = 72\tfrac{8}{11} \text{ H. P.}$$

Ques. 1833.—Find the horsepower of an engine having two cylinders 30 inches in diameter, and a 5-foot stroke, when making 60 strokes per minute, with an average steam-cylinder pressure of 30 pounds per square inch, and an average back pressure of 4 pounds per square inch. *M.—B. C., Canada*

ANS.—It is customary to calculate the horsepower of a duplex engine by calculating the power of one cylinder only, since the two cranks are set at right angles to each other on the crank-shaft, the one cylinder thereby exerting its full force when the other cylinder is powerless, its crank being on dead center. The average effective cylinder pressure in this case is $30-4 = 26$ lb. per sq. in. The horsepower of the engine is calculated thus:

$$H = \frac{plan}{33{,}000} = \frac{26\times 5\times(.7854\times 30^2)\times 60}{33{,}000} = 167.076 \text{ H. P.}$$

QUES. 1834.—The diameter of the piston of an engine is 10 inches and the length of stroke is 15 inches; the engine makes 250 revolutions per minute with a mean effective pressure of 40 pounds per square inch. What is the horsepower of the engine?

H.—Ia.

ANS.—The area of the piston in this case is $.7854\times 10^2 = 78.54$ sq. in. The piston speed when the engine is making 250 rev. per min. is

$$\frac{250\times 2\times 15}{12} = 625 \text{ ft. per min.}$$

The indicated horsepower of this engine is therefore

$$\text{I. H. P.} = \frac{40\times 78.54\times 625}{33{,}000} = 59.6 \text{ H. P.}$$

QUES. 1835.—A 300-horsepower engine has a cylinder 22 inches in diameter, and a stroke of 18 inches; when making 200 revolutions per minute, what must be the mean effective pressure (M.E.P.)?

H.—Ia.

ANS.—The area of the piston, in this case, is $.7854\times 22^2 = 380+$ sq. in.; the piston speed is

$$\frac{200\ (2\times 18)}{12} = 600 \text{ ft. per min.}$$

In order to develop 300 H. P., this engine must perform $300\times 33{,}000 = 9{,}900{,}000$ ft.-lb. of work each minute of time; or the total pressure on the piston must be $9{,}900{,}000 \div 600 = 16{,}500$ lb. The required mean effective pressure (M. E. P.) is then $16{,}500 \div 380 = 43.42$ lb. per sq. in.

QUES. 1836.—An engine showed by its card that it developed 60 horsepower. At the time the card was taken, the engine was pulling a load of 3 tons up a shaft, 148.5 feet in depth, in 30 seconds; what is the efficiency of the engine, the friction of the load being neglected?

H.—Ia.

ANS.—Ignoring friction, the horsepower consumed in lifting a load of 3 T. through a vertical height of 148.5 ft. in 30 sec. is

$$H = \frac{3\times 2{,}000\times 148.5}{33{,}000}\times\frac{60}{30} = 54 \text{ H. P.}$$

The efficiency of the engine in this case is therefore $\frac{54}{60}\times 100 = $ **90** per cent.

SETTING A STEAM VALVE

QUES. 1837.—How would you proceed to set a common slide valve? *H.—Ill.*

ANS.—To set the slide valve of an engine, first make a mark on the crosshead, then find the dead centers by rotating, the flywheel backwards, and marking exactly on the guide bars at the head and crank-ends the extreme points of travel of the crosshead mark. Next, having removed the steam-chest cover, rotate the flywheel in a forward direction until the crosshead mark and the head guide-bar mark coincide. Then secure the eccentric on the shaft a little more than a right angle in advance of the crank, if the engine is direct-connected, but if the engine is cross-connected place the eccentric a little more than a right angle behind the crank. Then turn the eccentric upon the shaft until the head end *a* of the valve and the extreme edge *b* of the head steam port coincide, as shown in Fig. 1. Now, rotate the flywheel in a forward direction until the crosshead and crank guide-bar marks coincide and note if in this position the points *c* and *d* coincide. If they do, the valve is properly set. If, however, the point *c* has passed *d*, the valve stem must be shortened a length equal to one-half the overreach; or, if *c* has not yet reached *d* and the crank-port is still closed, the valve stem must be lengthened an amount equal to one-half the distance lacking to open this port. The valve stem is now of the right length. Rotate the flywheel forwards until the crosshead and the head guide-bar marks again coincide, and once more turn the eccentric on the shaft until the head end *a* of the valve occupies a position denoted by *x*, when the distance *b x* will be equal to the required lead. Then fasten the eccentric securely to the shaft, replace the steam-chest cover, and the valve is set.

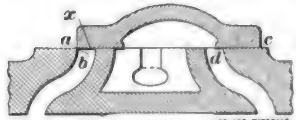

FIG. 1

QUES. 1838.—Name and define four important events in the distribution of steam, which occur in every revolution of an engine. *H.—Ia.*

ANS.—The four important points occurring in a single revolution of an engine are: The point of admission, when steam first begins to enter one of the steam ports of the cylinder. The point of cut-off, when the valve closes this steam port and no more steam is allowed to enter, say the head end of the cylinder; at this point, the expansion of the steam in this end of the cylinder begins. The point of compression, when the slide valve closes the exhaust port and no more steam is allowed to escape from the crank-end of the cylinder; at this point, the compression of the steam in this end of the cylinder begins. The point of release, when the slide valve begins to open the exhaust port and allow the escape of the expanded steam from the head end of the cylinder.

QUES. 1839.—How would you determine the point of admission of steam to an engine cylinder, and the point of cut-off?

H.—Ill.

ANS.—The points of admission and cut-off are determined, respectively, from the indicator card taken from the engine. It is often a difficult matter to determine these points exactly, especially when the engine has a leaky valve, or there is a rounding of the lines of the indicator card due to other causes; this is especially true at high rotative speeds. Experience is required and a thorough knowledge of the working of the engine and the effects of the compression and expansion of steam in the cylinder is necessary. The point of admission on the indicator card is determined by the first evidence the card shows of compression having ceased. The point of cut-off is often more difficult to determine than that of admission, but it is usually accomplished by producing the expansion line upwards to where it intersects the steam line of the diagram. Experimentally, the point of admission

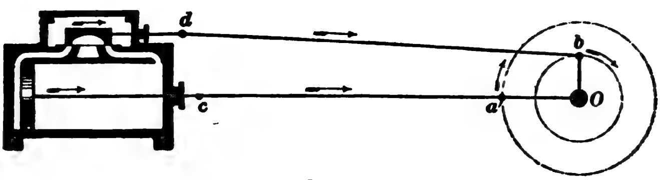

FIG. 2

in the stroke of an engine may be determined by turning the engine over and noting the point when steam first enters the cylinder, as indicated by its escape from the open drip cocks; but time must be given for the steam to fill the cylinder. Likewise, the point of cut-off is ascertained by noting the point at which steam ceases to escape from the drip cocks when the engine is turned over still further. These points may be marked by a scratch on the crosshead and a corresponding mark on the guide bar at each position of the engine. Marks should also be made to indicate the dead center at each end of the stroke.

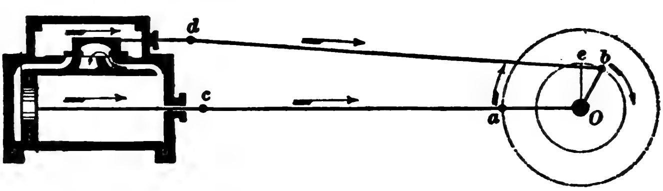

FIG. 3

QUES. 1840.—How should the eccentric be set where the valve has neither outside lap nor lead?

ANS.—In such a case, the eccentric should be set at right angles to the crank-arm. The valve will then just cover the two side ports of the cylinder when the piston is at either end of its stroke, as shown in Fig. 2.

QUES. 1841.—Where the valve has steam lap but no lead, how should the eccentric be set?

ANS.—In this case, when the crank is on dead center and the piston at one end of its stroke, Fig. 3, the eccentric should be set at a small angle in advance of its position when at right angles to the crank-arm. This angle must be such that the valve will just begin to open the steam port as the piston commences its stroke.

QUES. 1842.—What effect has inside lap on the time of admission? How does inside lap affect the point of cut-off? *H.—Ia.*

ANS.—Inside lap does not affect either the time of admission or the point of cut-off.

QUES. 1843.—Which will stand the greater inside lap, a condensing or a non-condensing engine? *H.—Ia.*

ANS.—A condensing engine will stand a greater inside lap than a non-condensing engine, because a greater lap means a greater amount of compression, and this is possible in proportion as the initial pressure or the pressure at which the compression begins is low, other things being equal. This initial pressure is lower in a condensing engine, owing to the discharge of the exhaust steam from the cylinder into the receiver of the condenser, instead of into the atmosphere, the pressure in the condenser always being less than that of the atmosphere.

QUES. 1844.—How can you tell when the valve has got lead, without opening the chest, if there are no punch marks to go by? *H.—Ia.*

ANS.—Turn the engine on center and open the drip cocks underneath the cylinder. If steam escapes, under pressure, from the cock at that end of the cylinder by the piston, it is either due to the valve being set with a lead or to a leak underneath the valve. To ascertain if the valve leaks, turn the engine slightly backwards, and if the steam is cut off, the valve is tight, but is set with a lead.

QUES. 1845.—What would you do if you found the face of your slide valve fitting badly to the valve seat? *H.—Ia.*

ANS.—A badly fitting slide valve is due either to a fault of construction or to the undue wear of the valve or valve seat. The remedy in the former case is to get a new valve; and in the latter case the valve should be removed and made to fit the valve seat uniformly by planing or regrinding it or the valve seat or both.

OPERATION AND CARE OF ENGINES

QUES. 1846.—What parts of stationary engines should receive particular attention at the beginning of each shift? *H.—Ia.*

ANS.—When starting an engine that has been idle for a period of time, particular attention should be given to see that all its bearings are in proper adjustment and cleaned and lubricated. The oil cups at the various joints and bearings should be supplied with oil. It is important to see that the drain cocks of the cylinders are open, and the cylinder free from any accumulation of water that may have drained from the steam pipes or formed from the condensation of the steam in the cylinder. If this is not done, serious damage to the engine may arise. The cylinder head may be forced off, or the piston broken from its stem, by the water, which may more than fill the clearance space and which is practically incompressible. This will produce a severe shock to the moving parts of the engine.

QUES. 1847.—What are the sources of the loss of heat in a steam engine? Does inside lap increase or diminish compression? *H.—Ia.*

ANS.—The principal source of the loss of heat in a steam engine occurs in the loss of steam, either through leakage, or condensation in the pipes and cylinders, and by the conduction and radiation of heat from the boilers, steam pipes, and cylinders. In a non-condensing engine, much heat is also carried off and lost by the exhaust steam; much of this heat, however, is saved in the best types of condensing engines.

Inside lap increases the compression of the steam by closing the exhaust port of the cylinder sooner.

QUES. 1848.—How would you open and close the valves that start and stop an engine, as slowly or as quickly as possible? Give reasons. *H.—Ia.*

ANS.—The throttle valve giving steam to an engine should not be opened and closed too quickly, as an unnecessary stress is thrown on the piston and cylinder and all the running gear of the engine when the valve is opened too quickly, and on the boiler and steam connections when closed quickly. This is especially the case in large engines using a large amount of steam and requiring large pipes and valves. The result when the throttle valve is closed quickly is similar to the water hammer produced in water pipes by the quick closing of a valve, but to a much less extent owing to the compressibility of the steam.

QUES. 1849.—How may cylinder heads be strengthened or stiffened? How may the tightness of a slide valve be tested?

ANS.—The cylinder heads of large engines are generally strengthened by casting them with radiating ribs of metal, which increases the strength of the head without very largely increasing the weight of metal used.

To ascertain the tightness of a steam slide valve or to discover if the valve leaks, the engine should be turned until the valve is in a central position so as to cover both the steam ports of the cylinder. While in this position, the drip cocks should be open at both ends of the cylinder and the steam turned on. If the valve is tight, there will be very little, if any, steam escaping from the drip cocks.

QUES. 1850.—How would you determine whether the piston or valves of an engine were leaking? *H.—Ia.*

ANS.—A practical method of doing this is to put the engine not quite on the center so that the valve opens the exhaust of one end while it just admits steam on the other. Open the drip cock of the first end and a leak shows itself by steam coming through. To distinguish between a leaky piston and a leaky valve take off the cylinder head of this same end and look in or feel whether it comes from the port or the piston. The operation can be repeated for the other end near the other center.

Leaking may be discovered by studying the indicator card taken from the cylinder as follows: The theoretical expansion line should be calculated and laid off on the indicator card. If the expansion line produced by the engine is above the theoretical line, this will indicate the leaking of live steam into the cylinder, after the valve has closed. If, however, the expansion line of the engine card lies below the theoretical expansion line, steam is leaking from the cylinder into the exhaust owing to defective packing of the piston. The ability to correctly read and interpret an engine card can only be attained by long experience in this work.

QUES. 1851.—Where is the common place for the piston rod to break? *H.—Ia.*

ANS.—The piston rod of an ordinary slide-valve engine is most liable to break at or near the crosshead, owing to the greater chance at this point for an indirect thrust on the piston rod to occur if the guides or the crosshead, or both, become somewhat worn.

QUES. 1852.—How may the water consumption of an engine be calculated? *H.—Ia.*

ANS.—Approximately, the water consumption of a steam engine may be calculated from its indicated horsepower on the basis of adopted standard horsepower for boilers, which is the evaporation of 34.5 lb. of water per H. P., per hour. For example, the water required for a boiler supplying steam to an engine of 100 H. P. will be approximately,

$$\frac{100 \times 34.5}{8.33} = 414 \text{ gal. per hour.}$$

This will be on the safe side; the actual figure is less in most cases.

QUES. 1853.—What is a stuffingbox, and how is it made airtight? *H.—Ia.*

Ans.—A stuffingbox is a cylindrical box attached to and surrounding an opening in a cylinder, boiler, or other vessel, for the purpose of holding the packing that is used to prevent the escape of the steam, air, or water confined under pressure in the vessel. Fig. 4 is a sectional view of a stuffing-box *a a*, through which the piston rod *b* passes; the space *c* surrounding the piston rod contains the packing, which is compressed tightly by the collar *d*. This collar is lined with a bushing *e* of brass or Babbitt metal that can be replaced when worn, the whole being drawn down and held by the bolts and nuts *f*, *f*. The packing, which may consist of rubber, asbestos, flax fiber, or metal, when compressed forms a steam- or air-tight seal.

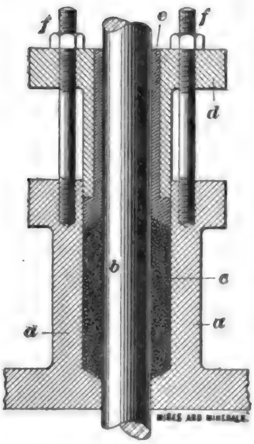

Fig. 4

KNOCK OF AN ENGINE

Ques. 1854.—If after you have set the valve and keyed everything properly there is still a knock in the engine, how would you locate it? *H.—Ia.*

Ans.—This a difficult question to answer satisfactorily, inasmuch as a knock of this sort, in an engine, is often an extremely difficult thing to locate. An engine may run for a great length of time with such a knock, before an experienced engineer can ascertain its cause. The knock in an engine is often found to arise from a loose crankpin, wristpin, or crosshead. It may occur from the looseness of the piston or follower on the piston rod, and in this case will prove a serious matter. A click sometimes occurs in the cylinder of an engine, due to the steam pressure gaining access to the packing rings of the piston, causing the ends of the ring to strike together and produce a clicking sound. A knock is sometimes produced by the striking of a key or wedge that has been driven up too far. There are numerous other causes that may occur to produce this trouble, but these can only be ascertained by extreme diligence, care, and skill on the part of the engineer.

Ques. 1855.—What would you do to stop a clicking noise in the cylinder? *H.—Ill.*

Ans.—The clicking that frequently occurs in the cylinder of an engine may be due to the steam pressure gaining access to the packing rings of the piston, causing the ends of these rings to strike together and produce a clicking sound. When this occurs, it is a difficult matter to fully eradicate the trouble. When the trouble is due to other causes, as when the valve is lifted from its seat by too strong a compression in the cylinder, relief may be had by reducing the period of compression or applying such other needed remedy as a careful scrutiny may suggest.

CHAPTER XXI

HOISTING

QUALIFICATIONS AND DUTIES OF A HOISTING ENGINEER

QUES. 1900.—What experience have you had with hoisting engines and boilers? *H.—Ia.*

ANS.—This question must be answered from the candidate's personal experience.

QUES. 1901.—Name the essential qualifications of a hoisting engineer as to character; habits; education; and experience. *H.—Ind.*

ANS.—He should be conscientious, upright, and honest, so that he can be depended on to be always at his post and to do his whole duty.

He should be sober, industrious, and attentive when on duty, cool and deliberate in action, and should avoid all habits that will tend to affect his nerves.

He should read the English language and write legibly, and understand arithmetic and be able to calculate the power of an engine or the power required to perform a certain work. He should have a good knowledge of mechanics and machinery. He should have a sufficient experience to understand the care of boilers and the proper methods of firing, and to quickly detect anything wrong in the steaming of the boilers, or the running of the engine, and be able to set the valves of an engine, and to make all the small repairs necessary to keep the machinery in his charge in running order; and to be well acquainted with the work of running an engine.

QUES. 1902.—What conditions should a good hoisting engineer fulfil? *H.—Ia.*

ANS.—Aside from the requirements of the mining law, a hoisting engineer should be conscientious, observant, and industrious; he should permit no trivial circumstance to interfere with the regular performance of his duties. A hoisting engineer should be a man of good judgment; he should form his opinion deliberately and carefully. He should be temperate and sober when off duty, and not indulge in habits that tend to weaken

him physically or mentally. An engineer should be a practical man, well informed in regard to the theory and practice of the operation of his engine. He should be alert, reliant, and determined; quick to see and hear, and prompt to respond to any signal that may be given.

QUES. 1903.—Define clearly the duties of a hoisting engineer. *H.—Ill.*

ANS.—A hoisting engineer should be promptly on hand at least 15 or 20 minutes before the time for taking charge of the engine, and should remain diligently at his post until relieved by another engineer. Before taking charge of the engine, he should examine the brakes, rope fastenings, oil cups, valves, journals, and other bearings, and assure himself that all are in proper condition. A hoisting engineer should be thoroughly acquainted with the signals in use, a copy of which should be posted in a conspicuous place in the engine room; he should also be acquainted with the State laws, if any exist relative to the hoisting of men. He should have a thorough knowledge of all the working parts of the engine and respond promptly to signals when they are given, always keeping the engine under complete control and within the proper limits of speed; he should not, however, move the cage from rest in response to a signal that is not clear and thoroughly understood. He should exercise special care when hoisting or lowering men. If an indicator is used in the engine room to show the position of the cage in the shaft, he should observe the same while hoisting, but should know by the lapping of the rope on the drum, or by a mark placed on the rope, when it is necessary to shut off steam and stop his engine. At the end of each shift, the engineer should turn over his engine in good condition to the man who follows him. He should not allow loiterers in the engine room and should not enter into conversation with any one while on duty.

QUES. 1904.—What are the duties of the bottom or signal man? What signals are given by him to the surface, as provided by the Special Rules? *M.—B. C., Canada*

ANS.—He shall prevent as far as possible any violation of the Rules that may come under his notice, and report the same to the manager or overman. He shall regulate the number of men ascending on the cage at one time, and attend to the proper loading of material. He shall give and answer all signals at the bottom of the shaft for the movement of the cage, examine regularly signal apparatus, cages, and guides in the shaft, and the cars used in the pit, and report their condition to the manager. He shall ring once for the ascent of the cage whether loaded with material or empty. When men are to ascend, he shall first ring three times in rapid succession, and after receiving a response from the surface indicating that all is ready, he shall then ring once for the ascent of the cage. He shall ring once to stop the cage when in motion, and twice for the engine to be reversed and the cage returned to the bottom of the shaft.

Ques. 1905.—In a shaft where three coal seams are being mined, what dangers are imminent in having three landings, and how would you avoid these dangers? *F.—Pa.* (*A*)

Ans.—Under these conditions, there is always danger of signals being taken as referring to the wrong landing; or signals may be given from one landing for the movement of the cage, and through neglect or mistake the engineer may fail to wait for the signals to be given from the landing where the cage is at the time. Again, the wings or keeps at any landing may accidentally extend into the shaft and catch the cage in its descent. The danger always exists of the safety gates being left open at any of the landings above the bottom, and men or animals walking into the shaft, or cars may fall into the shaft from one of the upper landings and strike the cage. These dangers should be guarded against by providing for each landing a distinct signal bell or gong that cannot be mistaken as belonging to any other landing than the one with which it is connected. The wires connecting the several landings with these bells or gongs, should be conducted down the shaft in a protected position, where they cannot be interfered with by the movement of the cage, or by men. Strict regulations should be enforced prohibiting the movement of the cage from any landing before the engineer has received and responded to the signal given at that landing. A cager, or bottom man, should be stationed at each landing, whose duty is to give all signals for the movement of the cage at that point, and to see that the gates are always in position; and when work is temporarily abandoned at any landing, the safety gates and wings should be locked or otherwise made secure.

HOISTING APPLIANCES

Ques. 1906.—What in your opinion constitutes an efficient and safe hoisting plant for a coal mine? Describe in detail from the foundation of the engine to the delivery of the carriage at the tipple. *I.—Pa.* (*A*)

Ans.—The hoisting engine should be a duplex engine of such size that each cylinder will be capable of picking up and handling the entire load on the engine at any point in the shaft. The engine and the winding drum should be firmly anchored to a heavy foundation of masonry. If the engine is a second-motion engine, the gear-wheel and pinion should be so protected as to avoid the possibility of anything dropping between them and breaking the teeth. The engine should be supplied with all the appliances necessary for the safe hoisting of men. The brake should be such that it can be quickly applied by the engineer while standing at the throttle; it should be capable of stopping and holding the cage and its load at any point of the hoist. An indicator should be so fixed as to show plainly the position of the cage in the shaft at any time and the hoisting rope should be marked with white paint to indicate the near approach of the cage to

a landing. The throttle for shutting off the supply of steam to the cylinders should be positive and certain in its action, and its mechanism should be such that it cannot fail to act at the proper moment. The winding drum of the engine should be of sufficient diameter to avoid producing an undue bending strain in the hoisting rope. The hoisting rope should be capable of withstanding a load at least five or six times the ordinary working load. The head-sheave should be well secured to the top of the head-frame, and should have such a diameter as not to produce an undue bending strain in the hoisting rope. The rope should be thoroughly secured in the socket by which it is attached to the cage, and bridle chains should be used connecting with the safety catches. The cage should be supplied with proper hoods or covers, and safety catches, and each landing should be provided with substantial safety gates, and a proper arrangement of wings or keeps on which the cage may rest. A speaking tube convenient to the engineer, should extend from the engine room to each landing. Proper signal apparatus should be kept in good working order, so that the engineer cannot fail to hear and understand all the signals given.

Ques. 1907.—What three articles belonging to the hoisting apparatus of a sinking shaft should be inspected every day?

F.—Ia.

Ans.—The ropes, and all hooks, swivels, clevises, chains, and other connections by which the rope is attached to the sinking bucket; also the safety catches where these are used and the brake on the drum of the hoisting engine should be carefully examined each day, as well as the buckets, the hoisting gear, and every part of the hoisting engine used while sinking the shaft.

Ques. 1908.—How should cage bonnets or covers be arranged and fitted on cages to insure the greatest amount of safety to cagers or other persons from coal falling back into the shaft?

F.—Ind.

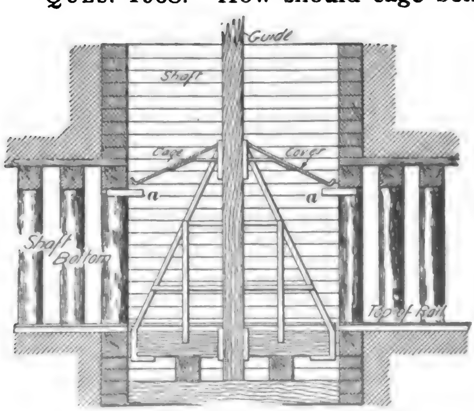

Fig. 1

Ans.—The bonnets or covers to a cage should be arranged with a slight slope toward each end of the cage, and should be large enough to practically cover the entire cage. To protect the cager at the shaft bottom, the cage bonnets should be high enough so that falling coal striking the bonnets will not be thrown directly into the entry. Suitable provision should be made against this by strong hoods *a*, Fig. 1, at the shaft bottom, fitting under the cage covers.

QUES. 1909.—An indicator attached to a winding drum is run by means of a gear-wheel meshing with a worm on the end of the shaft; the small gear-wheel that is connected to the pointer has sixteen teeth, and the circumference of the dial is 32 inches. How far will the pointer move for each revolution of the drum?

H.—Ia.

ANS.—The worm being on the drum shaft, one revolution of the worm corresponds to one revolution of the drum, and since there are sixteen teeth in the gear-wheel, it will require sixteen revolutions of the drum to produce one revolution of the pointer; and a single revolution of the drum will move the pointer

$$32 \div 16 = 2 \text{ in.}$$

EXAMINATION OF HOISTING APPLIANCES

QUES. 1910.—What special care is required to be given to hoisting ropes and cages? *M.—Ill.*

ANS.—Hoisting ropes and cages require careful daily inspection where men are being hoisted and lowered in a shaft. It is important to examine carefully all the fastenings by which the rope is attached to the cage, as well as the entire length of the rope, to detect any loose or broken wires; this examination is often made by allowing the rope to pass through the hands while the cage is being slowly lowered. It should also be observed whether the cage binds at any point in the shaft, and if this occurs such place should be watched carefully until the trouble can be remedied. The hoisting rope should be kept well lubricated and coated to protect it from the corrosive action of the acid mine water.

QUES. 1911.—How would you determine when a hoisting rope is unsafe, and what portion of the rope would you consider the weakest part or the part most liable to give out first?

F.—Pa. (B)

ANS.—Broken or badly worn wires are usually the first visible signs of failure in a hoisting rope. A close inspection may reveal internal wear or corrosion of the wires that would escape a superficial examination. It is often claimed that, in deep shafts at least, the upper portion of a hoisting rope is the first to weaken, owing to its being subjected to the severest shock and strain when starting the load off the bottom and again when bringing the cage to rest at the bottom; it usually happens, however, that because of rough usage or the corrosive effect of acid mine water the part of a hoisting rope where it begins to fail is at or near the socket that attaches the rope to the cage.

QUES. 1912.—How would you examine a hoisting rope? What indications would lead you to think that the rope was defective? *H.—Ind.*

ANS.—Instruct the engineer to run the engine slowly, and stand where a good view of the rope is obtained and watch for indications of broken wires or strands, at the same time allowing the rope to pass through the hands to catch any loose wires that may escape notice otherwise.

If the rope shows broken wires, or if it has materially lengthened or is worn by use, these are indications that it is becoming defective.

QUES. 1913.—State the method you would employ in making an examination of the rope, cage, and safety catches in use at a coal mine. *F.—Pa. (A)*

ANS.—The usual method of making an examination of a hoisting rope is to allow the rope to slip through the hand while the engine is being run slowly, in order to detect any broken wires. This examination is superficial, and only makes known breaks in the outer wires of the rope; it does not detect any internal wear or corrosion of the wires, which are so often the causes of the breaking of an apparently sound hoisting rope. There is no better test of the strength of the rope and couplings than is made by placing on the cage a load several times greater than the greatest load the rope is required to bear in practice, and then hoisting the cage gently a few feet above the shaft bottom. A loaded car should be next placed on the cage and the engineer instructed to start to hoist suddenly in order to ascertain the power of the rope to withstand any sudden jerk such as may occur in hoisting. The cage should be thoroughly examined to see that all nuts and rods are tight and that there are no evidences of breaks or excessive wear in the timber or metal parts and where the metal parts are subjected to the action of acid mine water especial care should be taken to detect corrosion due to such water. The guides in the shaft should be carefully inspected to ascertain if they are in sound condition and firmly secured at all points to the shaft curbing or buntons. The efficiency of the safety catches to arrest the fall of a loaded cage is tested by placing a loaded car on the cage; the cage should then be lifted from the wings on which it rests and the rope cut a short distance above the cage, allowing the latter to fall in the shaft until stopped by the action of the catches. This test may be made at the bottom of the shaft or at the top, but in the latter case supports are usually placed across the shaft so that the cage will not fall to the bottom and be destroyed in case the catches do not work. In some tests, a part of the shaft is chosen where the guides are wet and worn so as to give the severest test possible.

ROPE FASTENINGS

QUES. 1914.—What do you think is the safest and most convenient way of fastening a hoisting rope to a drum? *H.—Ia.*

ANS.—A hoisting rope should be fastened to the winding drum in such a manner as not to cause a sharp bend in the rope. There should always be set at least two or three coils of rope on the drum beyond what is required for hoisting; this will provide sufficient extra rope for cutting off the end of the rope at the cage and recapping it, which is the custom to avoid a break at this point. The end of the rope should be passed through a hole *a*, Fig. 2, in the lagging of the drum close to one side. After passing through the hole *a* the rope may be carried along a curved projection or rib *b* cast on the inside of the spider *c*, until it reaches the axis of the drum *d*, where, after one or two turns about the drum shaft, it is made secure by a clevis, or a small, narrow drum may be attached to the axis *d* and inside the lagging and about this end of the rope fastened.

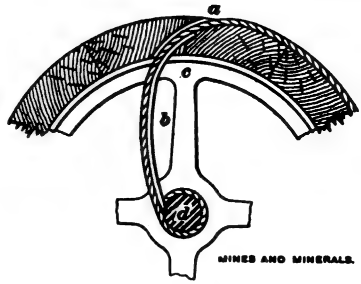

FIG. 2

QUES. 1915.—How would you fasten the hoisting cable to the cage? *H.—Ill.*

ANS.—The open socket (*a*), and the closed socket (*b*), Fig. 3, are the most common rope cappings employed for securing the rope to the cage. In each of these, the rope is first inserted in the hole of the socket and pulled through far enough to permit its strands to be untwisted and the wires bent back on themselves or turned inwards, thereby enlarging the end of the rope The hole of the socket being conical permits the rope to be then drawn back until the enlarged end of the rope holds it fast and prevents it from being drawn out of the socket. Small iron wedges are then driven in on the end of the rope, which is thus tightly wedged, making a firm fastening; or melted Babbitt metal or lead is poured into the end of the socket instead of driving the wedges. The open socket (*a*) is fastened to the ring of the bridle chain by means of a bolt, which is kept in place by a split key, as shown. The closed socket shown at (*b*) requires a

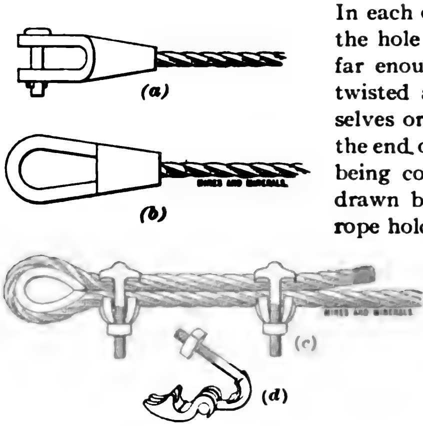

FIG. 3

link, coupling, or clevis to fasten it to the cage. Sometimes, the rope is bent around a steel thimble and fastened by two clamps, as shown at (*c*), the clamp being shown in detail at (*d*). This method of fastening is frequently employed when the rope requires to be often taken up or shortened on account of stretch, or owing to the extra wear at the end of the rope, and a link or clevis is then used to fasten the thimble to the cage.

SAFETY CATCHES

QUES. 1916.—Why are spring safety catches to be preferred to those operated by a weight and lever? *I.—Ia.*

ANS.—Because they are operated almost instantaneously by the force of the spring, which is not affected by the fall of the cage. Catches operated by a weight and lever do not act promptly in case of a sudden breaking of the hoisting rope, owing to the fact that the cage falls nearly as fast as the weights operating the catches.

QUES. 1917.—How would you make a test of safety catches? *E.—Ill.*

ANS.—The safety catches on a cage used for hoisting men should be carefully inspected each day to see that they are in proper working order. To test the efficiency of safety catches, if the head-frame is sufficiently high the cage is raised above the top platform and heavy timbers laid across the head of the shaft to catch the cage should the catches fail to work. The rope is then cut and the cage should be stopped by the catches.

HOISTING-SHEAVE SHAFT

QUES. 1918.—Determine the strain on the head-sheave over a hoisting shaft when the weight of the cage, car, load, and rope amounts to 15 tons, and the rope leaves the drum at an angle of 40°. What will be the diameter of the wrought-iron shaft of a head-sheave shaft, the bearings being 5 feet apart? *I.—Pa. (A)*

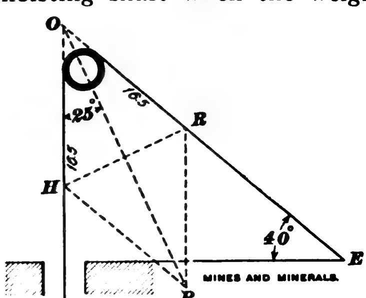

FIG. 4

ANS.—Adding one-tenth of the gross load as the load due to the friction of the hoist, the total load on the rope is 16.5 T. Fig. 4 is a diagram showing an elevation of the sheave and ropes, the lines of the rope in the shaft and the rope leading to the engine being extended until they intersect at *O*. Since the rope leading to the engine makes an

angle of 40° with the horizontal and the rope hanging in the shaft is vertical, the angle $E\,O\,H$ is 50°. With any convenient scale, lay off the distances $O\,R$ and $O\,H$ to represent 16.5 T. each, and complete the parallelogram of forces $O\,R\,P\,H$ and draw the diagonal $O\,P$ to represent the resultant of the weight in the shaft and the engine pull; this resultant $O\,P$ passes through the center of the sheave and bisects the angle $E\,O\,H$. Then $O\,P = 2\,(16.5 \times \cos 25°) = 33 \times .906 = 29.898$, say 30 T. To find the diameter of a wrought-iron shaft that will sustain a load of 30 T. when the distance between the bearings is 5 ft. (60 in.), first write the expression for the moment of inertia of a round beam referred to an axis passing through its center; thus, $\frac{\pi\,d^4}{64}$. The moment of resistance in a beam referred to its central axis is then found by multiplying this moment of inertia by the fiber stress f of the material, and dividing the result by one-half the diameter d of the beam, or, in this case, $\frac{\pi\,f\,d^3}{32}$. This moment of resistance in the beam must be equal to the moment of the load at the center, which is equal to one-half the load L multiplied by one-half the span l, or

$$\frac{L\,l}{4} = \frac{\pi\,f\,d^3}{32}$$

This gives for the expression of the load such a beam or shaft will support, after simplifying,

$$L = .3927\,\frac{f\,d^3}{l}$$

Substituting the given values in this formula, since

$$L = 30 \times 2{,}000 = 60{,}000 \text{ lb.};$$
$$f = 45{,}000 \text{ lb.};$$
$$l = 5 \times 12 = 60 \text{ in.};$$

d being the unknown diameter;

$$60{,}000 = .3927\,\frac{45{,}000\,d^3}{60};$$

and

$$d = \sqrt[3]{\frac{80}{.3927}} = 5.884, \text{ say 6 in.}$$

ROPES AND CHAINS

QUES. 1919.—What is the tensile strength of Norway iron? *M.—Ill.*

ANS.—It varies from 50,000 to 70,000 lb. per sq. in. of the cross-section of the iron.

QUES. 1920.—What size of bridle chain, in inches, should be used on a carriage where the cage and load weigh 12 tons? Use best quality of wrought iron. *I.—Pa. (A)*

Ans.—A common formula for determining the safe load L, in pounds, for an open-link chain made of wrought iron having a diameter d is $L = 12{,}000\ d^2$. In the present case, the load being $12 \times 2{,}000 = 24{,}000$ lb., the required diameter d will be

$$24{,}000 = 12{,}000\ d^2,$$

and

$$d = \sqrt{\frac{24{,}000}{12{,}000}} = \sqrt{2} = 1.4$$

Ques. 1921.—Give the breaking strain of an $\frac{11}{16}$-inch steel-wire rope. *M.—Ill.*

Ans.—The approximate breaking strength of a crucible cast-steel, six-strand, seven-wire rope, is given by the tables of the wire-rope manufacturers as 15.8 T.

Ques. 1922.—What will be a safe working load for a steel hoisting rope $\frac{7}{8}$ inch in diameter? *M.—Ill.*

Ans.—As in the previous question, the answer could be taken directly from the tables published by the makers of wire ropes, but it may be approximately calculated by the following empirical formulas based upon the strength of a 1-in. rope, as given by those tables.

If L_w = proper working load, in tons;
d = diameter of rope, in inches.

The proper working load for wire ropes may be expressed by the formulas

	6-Strand, 19-Wire Hoisting Ropes		6-Strand, 7-Wire Haulage Ropes	
For Swedish iron	$L_w = 17\frac{d^2}{f}$	(1)	$L_w = 16\frac{d^2}{f}$	(5)
For crucible cast steel	$L_w = 34\frac{d^2}{f}$	(2)	$L_w = 32\frac{d^2}{f}$	(6)
For extra-strong crucible cast steel	$L_w = 39\frac{d^2}{f}$	(3)	$L_w = 37\frac{d^2}{f}$	(7)
For plow steel	$L_w = 44\frac{d^2}{f}$	(4)	$L_w = 42\frac{d^2}{f}$	(8)

For a $\frac{7}{8}$-in. plow steel hoisting rope, the safe working load is, therefore, using a factor of safety $f = 5$,

$$W = \frac{44\ d^2}{5} = 8.8 \times .875^2 = 6.74 \text{ T}.$$

Ques. 1923.—A six-strand seven-wire cast-steel wire rope has a diameter of $1\frac{1}{4}$ inches; what safe load will it carry, using a factor of safety of 6? What is the minimum diameter of an open-link chain to carry the load in the foregoing example? *I.—Ia.*

Ans.—The approximate breaking strength of a six-strand seven-wire cast-steel rope $1\frac{1}{4}$ in. in diameter is given by the makers' tables as 48 T.

(2,000 lb. to the T.), and using a factor of safety of 6, the safe working load, $48 \div 6 = 8$ T. Using the empirical formula,

$$L_w = \frac{32\,d^2}{f};$$

$$L_w = \frac{32\,(1\tfrac{1}{4})^2}{6} = \frac{50}{6} = 8.3 \text{ T.}$$

Assuming a wrought-iron link having a breaking strength of 50,000 lb. per sq. in., the diameter of the round iron from which the link is forged, to sustain a safe load of 8 T., using a factor of safety of 6, is

$$d = \sqrt{\frac{6 \times 8 \times 2{,}000}{50{,}000 \times 2 \times .7854}} = 1.11 \text{ in. (about } 1\tfrac{1}{8} \text{ in.)}$$

Ques. 1924.—Give the breaking strain of a $\frac{9}{16}$-inch crucible cast-steel hoisting rope, six strands of nineteen wires each; also state the safe working load. *M.—Ill.*

Ans.—The breaking strain, in tons, of a six-strand nineteen-wire crucible cast-steel rope may be taken from the tables published by the makers of wire ropes or it may be calculated by substituting the given diameter of the rope for d in the following empirical formula based on those tables

$$S = 39\,d^2;\ S = 39 \times (\tfrac{9}{16})^2 = 12.3 \text{ T.}$$

The proper working load for wire ropes is generally assumed by manufacturers as one-fifth of the breaking strain, or, in this case, $12.3 \div 5 = 2.46$, say 2.5 T.

Ques. 1925.—What is the safe working load of a crucible-steel rope $1\frac{1}{4}$ inches in diameter, on a slope 600 feet long and pitching 30°? *I.—Pa. (A)*

Ans.—A crucible-steel rope $1\frac{1}{4}$ in. in diameter and nineteen wires to the strand weighs 2.45 lb. per linear foot; 600 feet, therefore, will weigh $600 \times 2.45 = 1{,}470$ lb. The proper working load of such a rope is given in the tables of the wire-rope manufacturers as 10 T. (2,000 lb. to the T.); hence, the net safe load that the rope can hoist vertically is $20{,}000 - 1{,}470 = 18{,}530$ lb. The load that the rope will hoist in a direction along the incline is equivalent to the vertical load divided by the sine of the angle of inclination, that is,

$$\frac{L}{\sin 30°} = \frac{18{,}530}{.5} = 37{,}060 \text{ lb.}$$

SIZE OF ROPE

Ques. 1926.—What size of steel-wire rope will be required to hoist a load of 3 tons from a shaft 200 feet deep, making due allowance for the weight of the rope? *I.—Ia.*

Ans.—For a crucible cast-steel six-strand nineteen-wire hoisting rope, adding one-tenth for the friction of the hoist, the size of rope required is given by the formula

$$d = \sqrt{\frac{f\,L_w}{.9(39) - \frac{1.58}{2{,}000}\,f\,D}}$$

in which d = diameter of rope, in inches;
D = depth of shaft, in feet;
f = factor of safety;
L_w = safe working load of rope, in tons.

Then, assuming a factor of safety $f = 5$, and substituting the given values $L = 3$ and $D = 200$, the required diameter of the rope is

$$d = \sqrt{\frac{5\times 3}{.9(39) - .00079\times 5\times 200}} = .66, \text{ say } \tfrac{3}{4} \text{ in.}$$

Ques. 1927.—What size of rope will be required to hoist a weight of 5 tons from a shaft 400 feet deep?

Ans.—In order to make allowance for the weight of the rope hanging in the shaft, and allowing one-tenth of the breaking strength of the rope to overcome the friction of the hoist, the formula given in answer to the preceding question is used. Substituting the given values $L = 5$ and $D = 400$, and assuming a factor of safety $f = 5$, the required diameter of a six-strand nineteen-wire hoisting rope of crucible steel is

$$d = \sqrt{\frac{5\times 5}{.9(39) - \frac{1.58}{2{,}000}\times 5\times 400}} = .86, \text{ say } \tfrac{7}{8} \text{ in.}$$

If a table of wire-rope values is available, it will be found that the proper working load for a $\frac{7}{8}$-in. crucible cast-steel rope is 5.2 T. Such a rope weighs 1.2 lb. per running foot, hence $400\times 1.2 = 480$ lb. for the weight of the rope. 480 lb. = .24 T., so that the total load on the rope will be 4.24 T., or slightly above the rated working load. The difference is so slight, however, that this rope would be used, unless extra precautions need be taken, in which case a $\frac{7}{8}$-in. extra-strong crucible steel rope could be used, as the proper working load for such a rope is 6 T.

WEAR OF ROPES

Ques. 1928.—When a rope carrying a load is run over a sheave wheel, to what two stresses is it subject? *H.—Ia.*

Ans.—The portion of the rope passing over the wheel is subject not only to the actual load that the rope is carrying, including the friction of the hoist, but also to a load due to the bending stress that is produced in the outer fibers of the rope. The same condition exists here as in a beam deflected under a heavy load, the outer fibers are extended, while the inner fibers are compressed.

Ques. 1929.—Name the conditions under which the rope is most likely to break in the shaft, and what would you recommend to guard against such contingencies? *F.—Pa.* (*A*)

Ans.—The breaking of a hoisting rope depends upon the size, kind, and condition of the rope, with respect to the load hoisted, the size of the head-sheaves over which the rope passes, the manner of capping the rope, the length of time the rope has been in service, the methods adopted for its preservation, the conditions under which it is used, and the manner in which the engineer handles the engine when hoisting. A rope must not only be of sufficient size and strength to support the actual load hoisted at any one time, including the friction of the hoist and the weight of the suspended rope, but must also be able to withstand the severest conditions incident to hoisting. Hence, in choosing a rope, a large factor of safety should be employed; a factor of safety of 5 is ordinarily used, but this should be increased to 10 in special cases. When a head-sheave of too small a diameter for the size of the rope is employed, an excessive bending strain is caused in the rope while passing over the sheave, which may quickly weaken the rope. One of the weakest points in a hoisting rope is where it enters the socket by which it is attached to the cage. It is customary, therefore, to cut off from 6 to 12 ft. of the end of the rope and recap the same from time to time. Another weak point occurs where the rope passes over the head-sheave, when one cage is at the shaft bottom and the other at the upper landing. The reason for this weak spot is the fact that the cages are so often brought to rest and remain in this position for a considerable time and the rope becomes set, besides being exposed to the action of the weather at this point. There is always produced besides, at the head-sheave, an excessive bending strain due to the starting of the load from the shaft bottom. A good practice when the engine is to be idle for any length of time, is to bring the cages to rest at some point in the shaft so as to avoid always exposing the same part of the rope to the weather and to the set of the sheave. The recapping of the rope from time to time will shift the spot of the rope subject to the excessive bending strain produced in starting the load from the bottom of the shaft. An engineer should not start the load suddenly from the shaft bottom. In shafts where the mine water contains much sulphur, the effects of corrosion should be guarded against as carefully as possible, by tarring and oiling the rope at regular periods. No rope used for hoisting men should be allowed to remain in service an indefinite period, or until it shows outward signs of weakness by the breaking of single wires. The external wear of a rope may or may not be manifested before the internal wear and corrosion has proceeded to an advanced stage. It is possible under certain conditions of severe service for the internal wear to cause the rupture of the rope before there is any evidence of external wear or weakness.

WEIGHT LIFTED BY ENGINE

Ques. 1930.—What weight will a single engine of the following dimensions lift: diameter of cylinder, 12 inches; length of stroke, 18 inches; average steam pressure, 50 pounds per square inch; geared 4 to 1; diameter of drum, 6 feet? *M.—B. C., Canada*

Ans.—The total cylinder pressure is

$$.7854 \times 12^2 \times 50 = 5,654.9 \text{ lb.}$$

The weight this engine will lift, disregarding friction, is, then,

$$\frac{5,654.9 \times 18 \times 4}{6 \times 12} = 5,654.9 \text{ lb.}$$

Ques. 1931.—What weight will a double-cylinder engine of the following dimensions lift allowing one cylinder to overcome friction: diameter of cylinder, 10 inches; length of stroke, 15 inches, steam pressure on pistons, 40 pounds per square inch; engine shaft geared 5 to 1 on drum; diameter of drum, 5 feet?

M.—B. C., Canada

Ans.—The lifting power in this case is

$$L = 40(.7854 \times 10^2)\frac{15}{5 \times 12} \times \frac{5}{1} = 3,927 \text{ lb.}$$

Ques. 1932.—If 33⅓ per cent. is allowed for friction, what weight can be lifted by a pair of first-motion engines, having cylinders 16 in. × 32 in. and a drum 8 feet in diameter, when the steam pressure is 60 pounds per square inch? *I.—Ia.*

Ans.—Having a cylinder pressure of 60 lb. per sq. in. and the diameter of the cylinder being 16 in., the total cylinder pressure is $.7854 \times 16^2 \times 60 = 12,064$ lb. Since the length of the stroke is 32 in., the crank-arm on the drum shaft is $32 \div 2 = 16$ in., and the moment of the cylinder pressure at the center of the drum shaft will be $12,064 \times 16$. Since the diameter of the drum is $8 \times 12 = 96$ in., the moment of the load W on the winding rope will be

$$\frac{W \times 96}{2} = 48\,W$$

These two moments must be equal to each other, and the total load lifted, including friction, is

$$W = 12,064 \times \frac{16}{48} = 4,021 \text{ lb.}$$

Since 33⅓ per cent. of this load is absorbed by the friction of the hoist, the net load hoisted is

$$4,021 \times \frac{2}{3} = 2,681 \text{ lb.}$$

QUES. 1933.—What is counterbalancing? Why is it necessary? How is it accomplished? *I.—Pa. (A)*

ANS.—Assuming that the question has reference to the counterbalancing required in hoisting from deep shafts, the term thus applied refers to the counterbalancing of the great weight of the hoisting rope, which is often equal to or greater than the net load hoisted.

In order to reduce the work of hoisting to an economical basis, in deep shafts, it is necessary to counterbalance the dead weight of the hoisting rope.

It is generally accomplished, in a double hoist, by a tail-rope suspended from the bottom of each cage. The weight of the tail-rope on the descending cage thus counterbalances the weight of the hoisting rope on the ascending cage. Sometimes the tail-rope is a continuous rope passing over a sheave between the hoistways at the bottom of the shaft, and having its two ends attached severally to the bottom of each cage. In either case, the weight of rope suspended in each hoisting compartment of a double shaft is always the same.

SIZE OF HOISTING ENGINE

QUES. 1934.—What kind and size of hoisting engine would you put in to hoist 1,200 tons of coal from a shaft 400 feet deep in 8 hours, with a steam pressure of 70 pounds, the weight of coal in each car being 3,000 pounds and allowing 20 per cent. for resistance of engines, ropes, and pulleys; allow time for caging the coal? *M.—Ill.*

ANS.—The load on the rope may be assumed as, coal 3,000 lb., car 2,000 lb., cage 3,500 lb.; total 8,500 lb. = 4.25 T. Using a factor of safety of 8, the size of rope required for this hoist is then,

$$d = \sqrt{\frac{8 \times 4.25}{.9(39) - \frac{1.58}{2,000} \times 8 \times 400}} = 1.02, \text{ say 1 in.}$$

The unbalanced load on the engine is the weight of the coal (3,000 lb.), and the weight of the rope ($400 \times 1.58 = 632$, say 700 lb.), making a total of 3,700 lb., not including the friction of the hoist. If 3,000 lb. of coal is hoisted each trip, there will be

$$\frac{1,200 \times 2,000}{3,000} = 800 \text{ hoists a day;}$$

or 100 hoists an hour, which allows

$$\frac{60 \times 60}{100} = 36 \text{ sec. per hoist}$$

Assuming an average speed of winding of 25 ft. per sec., the actual time of hoisting each trip is $400 \div 25 = 16$ sec., leaving $36 - 16 = 20$ sec. for changing cars each trip, and delays. Allowing 20 per cent. for all the

resistances, the efficiency of the hoist is $100-20 = 80$ per cent., and the required indicated horsepower of the engine is

$$H = \frac{3{,}700 \times 25 \times 60}{.8(33{,}000)} = 210+ \text{ H. P.}$$

Assuming a piston speed $S = 600$ ft. per min., and an efficiency of the engine $f = 90$ per cent., and taking the mean effective steam pressure in the cylinder as 70 lb., since the form of cut-off is not mentioned, and basing the calculation on developing the entire power in a single cylinder, as is good practice in hoisting, the diameter of the cylinder is

$$d = 205\sqrt{\frac{H}{f\,p\,S}} = 205\sqrt{\frac{210}{.9(70 \times 600)}} = 15.28+, \text{ say 16 in.}$$

Using a cast-steel six-strand nineteen-wire rope, the diameter of the drum should not be less than fifty times the diameter of the rope; hence, using a 5-ft. drum, the average velocity of the hoist being $v = 60 \times 25 = 1{,}500$ ft. per min., and the piston speed $S_p = 600$ ft. per min., the length of stroke for a direct-acting or first-motion engine is

$$l = \frac{\pi}{2}\,\frac{S_p}{v}\,D = \frac{3.1416}{2} \times \frac{600}{1{,}500}(5 \times 12) = 37+, \text{ say 38 in.}$$

A duplex first-motion engine 16 in. $\times$ 38 in., and developing 210 H. P. at a speed of 600 ft. per min., may be used for this hoist.

QUES. 1935.—What will be the size of the cylinder of a single engine, with gear-wheels in the ratio of 1 to 6, connected to a drum 5 feet in diameter, to hoist a weight of 4,000 pounds from a shaft 180 feet deep in 15 seconds? What will be the speed of the engine or the number of strokes per minute? What will be the piston speed?

ANS.—Assume an average steam pressure in the cylinder of 50 lb. per sq. in., and a ratio of length of stroke to diameter of cylinder of 2, and add one-fourth of the load for friction, weight of the rope, and the acceleration of the load, making the total load on the engine 5,000 lb. The required diameter of the cylinder is calculated by the formula

$$d = \sqrt[3]{2.54\,\frac{L\,R}{x\,r\,p\,e}};$$

in which d = diameter of cylinder, in inches;
L = load on engine, in pounds;
R = radius of drum, in inches;
p = mean effective cylinder pressure, in pounds per square inch;
r = ratio of length of stroke to diameter cylinder;
x = ratio of gearing;
e = efficiency of engine.

Substituting the given values in this formula $L = 5{,}000$; $R = \frac{5 \times 12}{2} = \frac{60}{2} = 30$; $p = 50$; $r = 2$; $x = 6$; $e = .6$,

$$d = \sqrt[3]{\frac{2.54 \times 5{,}000 \times 30}{6 \times 2 \times 50 \times .6}} = 10.19 \text{ in.};$$

a cylinder 10 in. in diameter would be used.

The number of strokes per minute is calculated from the speed of hoisting; namely, 180 ft. in 15 sec., or

$$\frac{180 \times 60}{15} = 720 \text{ ft. per min.}$$

The circumference of the drum is $3.1416 \times 5 = 15.7$ ft., and the drum therefore makes $720 \div 15.7 = 45.8$ rev. per min. The engine being geared 6 : 1, the speed of the engine is

$$45.8 \times 6 \times 2 = 549.6, \text{ say } 550 \text{ strokes per min.}$$

The length of stroke is $l = rd = 2 \times 10 = 20$, and the piston speed is, therefore,

$$\frac{20 \times 550}{12} = 916+ \text{ ft. per min.}$$

Ques. 1936.—It is required to raise 800 loaded mine cars daily, in a two-compartment shaft 400 yards deep. Give the general dimensions of the engine, drum, diameter of rope, etc. necessary to properly perform the work, assuming the weight of the load to be 3¼ tons, the weight of the car 1½ tons, the weight of the cage 1¼ tons, and the steam pressure 90 pounds per square inch.

I.—Pa. (A)

Ans.—Following is the load on the rope:

Coal	3¼ T.	=	6,500 lb.
Car	1½ T.	=	3,000 lb.
Cage	1¼ T.	=	2,500 lb.
1-in. rope		=	1,900 lb.
Total			13,900 lb.

Size of Rope.—The gross load or the entire moving load includes the weight of two cars, two cages, one rope, and one load of coal, making a total of 19,400 lb. Assume the friction of winding to be one-tenth of the gross load, or 1,940 lb., which added to the net load gives a total load on the rope of $13{,}900 + 1{,}940 = 15{,}840$ or about 16,000 lb. The proper working load for a 1⅛-in. crucible cast-steel rope is 8.4 T.

Speed of Hoisting.—Assuming that the 800 hoists are made in 10 hours, the time of hoisting is

$$\frac{10 \times 60 \times 60}{800} = 45 \text{ sec.}$$

for each hoist, including the time required for changing cars, and starting and stopping each trip. Assuming an average speed of hoisting of 40 ft. per sec., the actual time of hoisting each load is $1{,}200 \div 40 = 30$ sec. This gives $45 - 30 = 15$ sec. for changing cars, etc. Speed of hoisting, $40 \times 60 = 2{,}400$ ft. per min.

Diameter of Drum.—Assuming a direct-acting duplex engine making say, 150 strokes per min., which gives 75 rev. of the drum per min., the diameter of the drum is

$$d = \frac{2{,}400}{3.1416 \times 75} = 10+ \text{ ft.}$$

Mean Effective Cylinder Pressure.—Assuming that the engine cuts off at two-thirds stroke, the mean effective cylinder pressure may be calculated from the given boiler pressure (90 lb.), by using the formula

$$\text{M. E. P.} = .9\,[c(p+14.7)-17]$$

in which $c = .917$ for a two-thirds cut-off, and $p = 90$ lb.

$$\text{M. E. P.} = .9\,[.917(90+14.7)-17] = 71.1 \text{ lb. per sq. in.}$$

Load on the Engine.—Assuming that the weight of the car and cage is balanced, since this is a two-compartment shaft, the load on the engine is

Coal	6,500 lb.
1-in. rope, 2×1,200	2,400 lb.
Friction, 10 per cent	890 lb.
Total	9,790 lb

A load of 10,000 lb. may be used.

$$\text{Horsepower, } \frac{10{,}000 \times 2{,}400}{33{,}000} = 720+ \text{ H. P.}$$

Size of Engine.—Assuming the ratio of length of stroke to diameter of the cylinder as 1.5 and the efficiency of the engine as 60 per cent., the diameter of the cylinder may be calculated by the formula

$$d = \sqrt[3]{\frac{2.48\,L\,R}{r\,p\,e}} = \sqrt[3]{\frac{2.48 \times 10{,}000 \times 60}{1.5 \times 71.1 \times .6}} = 28.5$$

The length of stroke is $28 \times 1.5 = 42$ in. The size of engine required for this hoist is therefore 28 in. × 42 in.

QUES. 1937.—Find the diameter and length of stroke of the cylinder for a pair of direct-coupled winding engines, to raise 600 tons of coal in 7 hours from a shaft 400 feet deep, by single-decked cages carrying 1 ton of coal each winding, the proportion of length of stroke to diameter of cylinder being 2 : 1, and the mean effective steam pressure 50 pounds per square inch and the efficiency of the engine of 90 per cent.; also, give size of rope and diameter of drum required.

ANS.—Allowing 20 min. each day for unavoidable delays, making the total time of hoisting

$$7 \times 60 - 20 = 400 \text{ min.}$$

The output per day being 600 T., and 1 T. being hoisted at each winding, there will be 600 hoists made in 400 min., making the average time allowed for each hoist

$$\frac{400 \times 60}{600} = 40 \text{ sec.}$$

Allowing 20 sec. per hoist for changing cars, the actual time of hoisting each trip is $40-20 = 20$ sec., and the average speed of winding is then $400 \div 20 = 20$ ft. per sec.

To find the size of engine required for this hoist it will be necessary to calculate first the load on the engine, the size of the drum, and the power required for each hoist. Assuming a second-motion engine geared 5 : 2, and making 150 rev. per min., the drum will make

$$\frac{2}{5}\times 150 = 60 \text{ rev. per min.},$$

and the speed of winding being 20 ft. per sec., the required circumference of the drum is

$$\frac{20\times 60}{60} = 20 \text{ ft.},$$

and the diameter of the drum is

$$\sqrt{\frac{20}{.7854}} = 6.33 \text{ ft.} = 76 \text{ in.}$$

To find the load on the engine, it is necessary to calculate the load on the rope, and the size of rope. The approximate load on the rope is as follows: coal, 2,000 lb.; car, assume 1,400 lb.; cage, 2,400 lb.; total, 5,800 lb.

Taking a factor of safety of 10, which will well make suitable provision for shock and friction, and substituting the given values in the formula for finding the required diameter of a crucible cast-steel six-strand nineteen-wire hoisting rope is

$$d = \sqrt{\frac{10\times 3}{.9(39) - \frac{1.58}{2{,}000}\times 10\times 400}} = .96, \text{ say 1 in.}$$

A 1-in. wire rope weighs 1.58 lb. per running foot, and the weight of the rope in this case is therefore $1.58\times 400 = 632$ lb. The friction of the hoist is often taken as one-tenth of the gross load. The gross load is then: coal, 2,000 lb.; two cars, 2,800 lb.; two cages, 4,800 lb.; rope, 632 lb.; total, 10,232 lb., or approximately 10,000 lb.; and taking one-tenth of this as the total friction of the hoist, it is 1,000 lb. The unbalanced load on the engine is then: coal, 2,000 lb.; rope, 632 lb.; friction, 1,000 lb.; total, 3,632 lb., or approximately 3,700 lb.

The formula for finding the diameter of a steam cylinder when the load on the engine, the diameter of the drum, and the steam cylinder pressure are given is as follows:

$$d = \sqrt{\frac{2.54\, L\, R}{x\, r\, p\, e}}$$

In this case, $x = 2$; $r = 5 \div 2 = 2.5$; $p = 50$; $e = .90$; substituting these values in the formula

$$d = \sqrt{\frac{2.54\times 3{,}700\times 38}{2\times 2.5\times 50\times .9}} = 12 \text{ in.}$$

The length of stroke is then $2\times 12 = 24$ in., and the size of the engine required is therefore 12 in. $\times$ 24 in.

HORSEPOWER REQUIRED TO HOIST

QUES. 1938.—What horsepower is required to raise 4,500 pounds of coal through a shaft 400 feet in depth, in 22 seconds; the friction of engine, drum, sheave wheels, and guides being taken at one-fiftieth of the load; the cages weighing 2,500 pounds, the rope being $1\frac{1}{4}$-inch steel? *H.—Ill.*

ANS.—The weight of a $1\frac{1}{4}$-inch steel rope is 2.45 lb. per lin. ft.; the weight of the rope hanging in the shaft is therefore $2.45 \times 400 = 980$, say 1,000 lb. Assuming the weight of the empty car as 1,800 lb., the weight of one cage being 2,500 lb., and the weight of coal per hoist 4,500 lb., the total weight hoisted at one time is

$$\overset{\text{Car}}{1{,}800} + \overset{\text{Coal}}{4{,}500} + \overset{\text{Cage}}{2{,}500} + \overset{\text{Rope}}{1{,}000} = 9{,}800 \text{ lb.}$$

For a double hoist employing two cages and two cars, the friction being one-fiftieth of the gross moving load, first find the gross moving load as follows:

$$\overset{\text{Two Cars}}{3{,}600} + \overset{\text{Coal}}{4{,}500} + \overset{\text{Two Cages}}{5{,}000} + \overset{\text{Rope}}{1{,}000} = 14{,}100 \text{ lb.}$$

Taking for the friction one-fiftieth of this gross load, $14{,}100 \div 50 = 282$, say 300 lb. The total unbalanced load on the engine is then as follows:

$$\overset{\text{Coal}}{4{,}500} + \overset{\text{Rope}}{1{,}000} + \overset{\text{Friction}}{300} = 5{,}800 \text{ lb.}$$

The indicated horsepower required to hoist this load from this shaft in the given time is

$$H = \frac{5{,}800 \times 400 \times 60}{33{,}000 \times 22} = 191.7 \text{ H. P.}$$

QUES. 1939.—How many horsepower will it take to pull twenty loaded cars up an incline 400 feet long in 1 minute, the weight of coal in each car being 3,000 pounds, and the weight of the empty car 900 pounds; the resistance of rope and pulleys is 13 per cent. and the grade 7 per cent.? *M.—Ill.*

ANS.—An approximate method of calculating the horsepower, in this case assuming an unbalanced hoist, is to multiply the load, or weight of coal and cars hoisted per trip, by the vertical height of the incline, and divide by 33,000; thus,

$$H = \frac{20(3{,}000 + 900)(1.13)(400 \times .07)}{33{,}000} = 74.78+ \text{ H. P.}$$

QUES. 1940.—How many pounds of coal will be consumed in raising 1,000 tons of coal from a depth of 400 feet, the resistance of the engines, ropes, sheaves, cages, etc. being 10 per cent. of

the load, and the efficiency of the fuel in boilers and engines 7 per cent.? *I.—Ill.*

ANS.—The first step is to determine the total time consumed in hoisting the 1,000 lb. of coal in this shaft, and the horsepower required.

Time Required for Hoisting.—Assuming an average speed of winding of 20 ft. per sec., the time of hoisting is $400 \div 20 = 20$ sec. Allowing 10 sec. for change of cars and starting and stopping each trip, the total time per hoist is $20 + 10 = 30$ sec. Assuming the weight of coal per hoist as 1 T., the total time required for hoisting 1,000 T. will be

$$\frac{1{,}000 \times 30}{1 \times 60 \times 60} = 8\tfrac{1}{3} \text{ hr.}$$

Horsepower Required.—First, to determine the size of rope required, the total load hoisted is

$$\underset{\text{Coal}}{2{,}000} + \underset{\text{Car}}{1{,}000} + \underset{\text{Cage}}{2{,}000} + \underset{\text{Rope and Friction}}{600} = 5{,}600 \text{ lb.}$$

Doubling this to provide against shock, the working load upon the rope is

$$\frac{5{,}600 \times 2}{2{,}000} = 5.6 \text{ T.}$$

The proper working load for a crucible cast-steel six-strand nineteen-wire ⅞-in. rope, weighing 1.2 lb. per ft. is 5.2 T., but since the load has been doubled to allow for shock, the ⅞-in. rope would be used. The total weight of this rope is $1.2 \times 400 = 480$ lb., and the total moving load is then,

$$\underset{\text{Coal}}{2{,}000} + \underset{\text{Rope}}{480} + \underset{\text{Two Cages}}{2(2{,}000)} + \underset{\text{Two Cars}}{2(1{,}000)} = 8{,}480 \text{ lb.}$$

Allowing one-tenth of this total moving load for the friction of the hoist, the total unbalanced load on the engine is

$$\underset{\text{Coal}}{2{,}000} + \underset{\text{Rope}}{480} + \underset{\text{Friction}}{848} = 3{,}328 \text{ lb.}$$

And the horsepower required is

$$H = \frac{3{,}328 \times 20 \times 60}{33{,}000} = 121 \text{ I. H. P.}$$

Assuming the efficiency of the engine as .9, the total horsepower exerted by the engine is $121 \div .9 = 134+$ H. P.

Total Coal Burned.—Assuming that each pound of the coal burned contains 12,000 B. T. U., the coal has an efficiency of .07, and each thermal unit is equal to 778 ft.-lb.; each pound of coal burned under the boilers will develop

$$.07\,(12{,}000 \times 778) = 653{,}520 \text{ ft.-lb.}$$

But 1 H. P. will perform $33{,}000 \times 60 = 1{,}980{,}000$ ft.-lb. of work per hour, and the coal required is therefore

$$1{,}980{,}000 \div 653{,}520 = 3.03, \text{ say 3 lb. per H. P. per hr.}$$

The total coal required for this hoist, under the conditions named, is then,

$$\frac{3\times 134\times 8\frac{1}{3}}{2{,}000} = 1.675 \text{ T.}$$

LEGAL HOISTING REQUIREMENTS

Ques. 1941.—What are the legal requirements at shaft mines for lowering and hoisting persons employed therein?

F.—Pa. (B)

Ans.—The Bituminous Mine Law of Pennsylvania requires that in any mine operated by a shaft exceeding 75 ft. in vertical depth, the persons shall be lowered and raised from the mine by means of machinery, and also that the escape shaft or second opening shall be supplied with safe and suitable machinery for hoisting, or fitted with safe and convenient stairs, except where the mine is operated by two shafts equipped with safe and suitable hoisting machinery. The law prohibits the lowering or hoisting at one time of more persons than may be permitted by the mine inspector of the district, and notice of such number of persons signed by the mine inspector shall be kept posted in a conspicuous place at the top and bottom of the shaft, and requires that whenever such number of persons shall arrive at the bottom of the shaft where men are regularly hoisted and lowered, they shall be given an empty cage and hoisted to the surface, and in case of emergency a less number shall be promptly hoisted. Any person crowding or pushing to get on or off a cage shall be guilty of a misdemeanor. It requires the hoisting engineer to take special precautions to keep his engine under control when hoisting or lowering men and prohibits the hoisting or lowering at one time in a shaft of a greater number of persons than is permitted by the mine inspector.

Ques. 1942.—What are the provisions of Rules 17 and 57 of the general rules, Article 12 of the Anthracite Mining Law of Pennsylvania? *I.—Pa. (A)*

Ans.—Rule 17 provides that not more than ten persons shall be hoisted or lowered at one time in any shaft or slope, except on slopes where two or more loaded cars are regularly hoisted in a trip, in which case, at the request of at least thirty of the workmen, made in writing to the mine inspector of the district, the number of persons hoisted at one time may be increased to twenty, if in the judgment of the inspector the hoisting appliances are in every respect sufficiently strong. This rule also provides that whenever five persons shall arrive at the bottom of the shaft or slope they shall be furnished with an empty car or carriage and be hoisted, except where a traveling way having an average pitch not exceeding 15° and a length not exceeding 1,000 ft. is provided. Rule 57 provides that a fine of $50 shall be imposed on any superintendent or foreman who shall prevent the foot-man from complying with this rule.

QUES. 1943.—Give in substance the laws intended for the prevention of accidents in hoisting shafts in Indiana. *F.—Ind.*

ANS.—None but sober and competent engineers shall be placed in charge of any engine used for hoisting or lowering men. An adequate brake shall be attached to every drum or machine used for hoisting; also an indicator to show the position of the cage in the shaft. The hoisting signals used shall be posted at the top and bottom of the shaft and in the engine room. A wire rope shall be used for hoisting, and it shall be examined every morning by a competent person. Cages must be covered and have approved safety catches attached to them. Safety gates must be placed at all landings. Signal bells must be placed at the bottom of each shaft connecting with the engine room. Reflecting lights must be placed within 10 ft. of the shaft at any vein worked above the bottom of the shaft. A traveling way must be cut in the side of the shaft.

QUES. 1944.—Give the signal law that is required to be posted in the engine room at mines in Indiana. *H.—Ind.*

ANS.—There shall be a code of signals at all coal shafts in this State, and a signal bell shall be provided at the bottom of each shaft. One bell shall signify to hoist coal or empty cage, and also to stop either, when in motion; two bells shall signify that men are coming up. When return signal is received from the engineer, men will get on the cage, and ring one bell to hoist. The engineer's signal for men to get on the cage shall be three bells. Four bells shall signify to hoist slowly, implying danger.

QUES. 1945.—Give, in substance, the law relating to the qualifications of hoisting engineers at coal mines in Indiana. *H.—Ind.*

ANS.—None but experienced, competent, and sober engineers can be employed as hoisting engineers at any mine, nor any who have not received from the inspector of mines a certificate of service or of competency.

QUES. 1946.—What does the Illinois Mine law require as to the care of men in raising or lowering them in a shaft or slope? *M.—Ill.*

ANS.—The State Mine Law of Illinois reads as follows:

SEC. 2, (*c*). *Gates At the Top.*—The upper and the lower landings at the top of each shaft, and the opening of each intermediate seam from or to the shaft, shall be kept clear and free from loose materials, and shall be securely fenced with automatic or other gates, so as to prevent either men or materials from falling into the shaft.

SEC. 2, (*d*). *General Equipment.*—Every hoisting shaft must be equipped with substantial cages fitted to guide-rails running from the top to the bottom. Said cages must be safely constructed; they must be furnished with suitable boiler-iron covers to protect persons riding thereon from falling objects; they must be equipped with safety catches. Every cage on which persons are carried must be fitted up with iron bars or rings in proper place and sufficient number to furnish a secure handhold for every person permitted

to ride thereon. At the top landing, cage supports where necessary, must be carefully set and adjusted so as to act automatically and securely hold the cages when at rest.

SEC. 16, (*e*). *Care of Ropes, Cages, Etc.*—The mine manager or superintendent must have special attention given to the condition of the hoisting ropes; they must be carefully and frequently scrutinized. Before the men are lowered in the morning the soundness of the ropes must be tested by hoisting the cages. He must also have the cages, safety catches, pumps, sumps, and stables examined frequently; he must have the mine examined every morning by the mine examiner, before men are allowed to go to work; and know that the top man and bottom man are on duty, and that sufficient lights are maintained at the top and bottom landings when the men are being hoisted and lowered.

SEC. 16, (*f*). *Early and Late Duty.*—The mine manager or his agent shall be at his post at the mine when the men are lowered into the mine in the morning for work; he shall by some device keep a record of the number of men lowered either for a day or night shift, and he or his agent shall remain at night until all the men employed during the day shall have been hoisted out.

SEC. 17, (*d*). *Signals.*—The engineer must thoroughly understand the established code of signals, and these must be delivered in the engine room in a clear and unmistakable manner, and when he has the signal that the men are on the cage he must work his engine only at the rate of speed hereafter specified in this act.

SEC. 17, (*e*). *Handling of Engines.*—The engineer shall permit no one to handle or meddle with any machinery under his charge, nor suffer any one who is not a certificated engineer to operate his engine, except for the purpose of learning to operate it, and then only in the presence of the engineer in charge, and when men are not on the cage.

SEC. 28, (*a*). *Top Man and Bottom Man.*—At every shaft operated by steam power, the operator must station at the top and at the bottom of such shaft a competent man charged with the duty of attending to signals, preserving order, and enforcing the rules governing the carriage of men on cages. Said top man and bottom man shall be at their respective posts of duty at least a half hour before the hoisting of coal begins in the morning, and remain for a half hour after hoisting ceases for the day.

SEC. 28, (*b*). *Lights on Landings.*—Whenever the hoisting or lowering of men occurs before daylight, or after dark, or when the landing at which men take or leave the cage is at all obscured by steam or otherwise, there must always be maintained at such landing a light sufficient to show the landing and surrounding objects distinctly. Likewise, as long as there are men underground in any mine, the operator shall maintain a good and sufficient light at the bottom of the shaft thereof, so that persons coming to the bottom may clearly discern the cage and objects in the vicinity.

SEC. 28, (*c*). *Speed of Cages and Other Regulations.*—Cages on which men are riding shall not be lifted or lowered at a rate of speed greater than 600 feet per minute, except with the written consent of the inspector. No person shall carry any tools, timber, or other materials with him on the cage in motion, except for use in repairing the shaft; and no one shall ride on a cage containing either a loaded or empty car. No cage having an unstable or self-dumping platform shall be used for the carriage of men or materials unless the same is provided with some convenient device by which said platform can be securely locked, and unless it is so locked whenever men or materials are being conveyed thereon. No coal shall be hoisted in any shaft while men are being lowered therein.

QUES. 1947.—What are the requirements of the Illinois Mine Law in reference to brakes, drums, and ropes? *H.—Ill.*

Ans.—Section 4 of the mining law of Illinois reads in part as follows:

(b) *Brake or Drum.*—Every hoisting engine shall be provided with a good and sufficient brake on the drum, so adjusted that it may be operated by the engineer without leaving his post at the levers.

(c) *Flanges.*—Flanges shall be attached to the sides of the drum of any engine used for hoisting men, with a clearance of not less than 4 inches when the whole rope is wound on the drum.

(d) *Cable Fastenings.*—The ends of the hoisting cables shall be well secured on the drum and at least 2½ laps of the same shall remain on the drum when the cage is at rest at the lowest caging place in the shaft.

Ques. 1948.—What precautions are necessary to prevent accidents in lowering and hoisting persons in shafts?

I.—Pa. (B)

Ans.—The Pennsylvania Bituminous Mine Law requires that all machinery for lowering or raising persons at any mine shall be approved by the mine inspector of the district, and shall be inspected once each 24 hours by a competent person employed for that purpose; that a metal speaking tube, and proper means of signaling, shall be maintained between the top and bottom of the shaft; that every cage or carriage shall be provided with an overhead covering and with safety catches; that the winding drum shall be provided with flanges of at least 4 in. on each side of the drum, and adequate brakes and safety gates approved by the mine inspector of the district shall be placed at the top of the shaft; the coupling chain attaching the cage to the socket of the wire rope shall be of the best quality of iron, and tested by weights or otherwise, to the satisfaction of the district mine inspector; and bridle chains shall be attached to the main hoisting rope above the socket, and to the top cross-piece of the cage; no greater number of persons shall be lowered or hoisted at one time than is permitted by the inspector of the district, and notice of such number, signed by the district mine inspector, shall be kept posted by the operator or superintendent at the top and bottom of the shaft; no unauthorized person shall enter the engine house or handle or run the engine; a head-man and footman shall be employed, and be always at their respective places at the top and bottom of the shaft, while persons are being raised or lowered; they shall see that all persons raised or lowered comply with the regulations; that tools shall not be hoisted or lowered at the same time with persons, except for the purpose of repairing the shaft or machinery; no driver or other person shall ascend the shaft with any horse or mule, except the latter be secured in a suitable box or pen.

CHAPTER XXII

HAULAGE

MINE HAULAGE ROADS

QUES. 2000.—What is the first essential to the economical hauling of coal? *F_1.—Ala.*

ANS.—The first consideration of importance is that the grades of the haulage roads shall be uniform as far as practicable and favor the movement of the loaded cars. The condition of the rolling stock, size of car wheels, and the general condition of the tracks, kind of rails, size of rails, etc., all affect the question of economical haulage.

QUES. 2001.—What are the principal things to be looked after in haulage roads? *F_2.—Ala.*

ANS.—The essential points in reference to haulage roads are the following: They should be well timbered and daily inspected. They should be driven as straight as possible, and should maintain as uniform a grade as possible; it is a great advantage to change the grades of main haulage roads by shooting down top or lifting bottom when necessary, so as to produce a uniform grade. Haulage roads should not be driven less than 8 feet wide and should, in all cases, give ample room for men to pass on at least one side of the track. The haulage road should be well drained, and wet places where the bottom is soft should be corduroyed. The height of the haulage road should be sufficient to allow a good-sized mule to pass under the collars readily.

QUES. 2002.—How do a difference of grade, condition of bottom, and drainage affect the character of haulage roads in coal mines? *F.—Pa. (B)*

ANS.—The effects of grade are positive or negative; positive acting to increase the necessary power when hauling up grade, and negative acting to decrease the necessary power when hauling down grade. This increase or decrease of power due to grade varies directly as the sine of the grade. When the grade produces a fall sufficient for traction, no power is required. A good track cannot be laid on a hard, rocky bottom; consequently, the

bed requires to be ballasted with some material that will not be softened by water and will support the ties at a sufficient elevation for side drainage. When a track is laid on a soft, wet bed, the haulage is unduly heavy, as the ties settle into it and throw the rails so much out of level that the cars are derailed, and damage and loss of time result. In all cases, the best tracks are well drained and have the ties embedded in some material that is elastic without yielding to the pounding action produced by heavy loads passing over them.

QUES. 2003.—Describe how you would construct a good haulage road in a mine in which the bottom is very soft and making a great deal of water. *F.—Ind.*

ANS.—The roadway here should be corduroyed by laying cross-timbers or ties close together under the track. The entry or haulage way should be 12 to 14 feet wide, provided that the roof can be supported, and a good ditch for drainage should be maintained on one or both sides of the road as required, close to the track. The aim should be to keep the bottom dry and the track in good condition.

QUES. 2004.—How would you lay a good haulage road in the main entry, to secure good results and duration? *H.—Ia.*

ANS.—It is important when laying out a good haulage road to make the entry as straight, and provide as uniform a grade as possible. Where the seam is irregular, rising and falling at intervals, it is better to first make a profile of the entry and from it establish a good grade line, which will determine the points in the entry where roof must be taken down or bottom lifted before laying the track. It is also important that the road be well drained. This is generally accomplished by shallow ditches carried on one or both sides of the track. When the roadbed has been properly prepared, ties are laid down and the rails spiked to them and bolted together with rail splices. The track is then lined and leveled up or brought to grade by suitable ballast. The size of the track ties and the weight or size of the iron used is important and will depend on the system of haulage in use. Where motors are used and the cars are heavy, from 20-lb. to 50-lb. rails should be used, depending on the weight of the motor and the speed of travel. Light rails and small ties are not to be recommended for use on a main road. Haulage roads should be well timbered with sets where necessary, and lagging should be used where the roof is poor. At points where the roadbed is soft, it should be corduroyed by laying the track ties close together. Under ordinary conditions in mine work, the track ties are laid about 2 ft. from center to center.

QUES. 2005.—What are the important points to be considered in selecting a site for a double parting to be used as a gathering place for loaded cars? *F.—Ind.*

Ans.—The location of the inside parting should be convenient to the several haulage districts of the mine. In order that the trips in any one district shall not be too long, it may be necessary to provide two partings for making up the trips from these districts. The inside haul for gathering cars should not much exceed 1,500 to 2,000 ft., save in special cases where this cannot be avoided, and a smaller distance is often advantageous.

Ques. 2006.—In laying out a siding or main parting where mechanical haulage is in use, what are the chief points to be considered with reference to safety, economy, and the speedy handling of the coal? *F.—Pa.* (*B*)

Ans.—The parting should be well timbered with double timber but no center posts should be used. There should be ample room for mules to pass between the cars standing on the main track and siding. To facilitate the work, when practicable, the empty track may be given a grade of 6 in. per 100 ft. in favor of the empty cars, while the loaded track may have a similar grade in favor of the loaded cars. Spring latches should be provided at each end of the parting: at the outby end, the latches should be set for the empty track; while at the inby end, they are set for the loaded track. In rope haulage, the tail-sheave must be strongly anchored at the inby end of the parting in such a position as to be out of the way of the cars passing on to the siding. The rope passing on and off from this sheave should be guided by strong rollers or sheaves in such a manner as not to endanger the work of making up the trips.

GRADE OF HAULAGE ROADS

Ques. 2007.—What do you consider the best grade for haulage by animal power? *F.—Pa.* (*B*)

Ans.—Attention must be paid to the haulage of the loads toward the shaft as well as the haulage of the empty cars in the opposite direction. When possible, the grade should be in favor of the load, and should be at least 5 in. in 100 ft. to insure flow in the gutters alongside the track. On main roads, where cars having a capacity of 1½ to 2½ T. are hauled by animal power, the grades should not exceed 1 to 2 per cent. in favor of the loaded car. Such a rate of grade provides for an easy return haul of the empty trip without wearing out the stock, and likewise insures good drainage. With grades under 1 per cent., unless the ditches are kept perfectly clean the drainage is apt to be sluggish, and then, in low places, there is sure to be a wet and muddy track, which is a great waste of energy. Much depends on the character and condition of the road and the condition of the cars. The grade should be such that the loads will gravitate easily toward the shaft when practicable. The grade toward the shaft should not be so great as to run any risk of losing control of the cars and it should not be sufficient to necessitate the use of sprags.

QUES. 2008.—At what inclination should the tracks of a haulage road be laid, so that the resistance of the loaded trip shall be equal to the resistance of the empty trip under the following conditions: the cars each weigh when empty 1,500 pounds, when loaded 5,000 pounds; the coefficient of resistance of the track, car wheels, and axles being taken as .01667? *I.—Ill.*

ANS.—Apply the formula

$$\tan a = \mu \frac{w_c}{2W + w_c}$$

in which a = inclination of plane;
W = weight of empty car, in pounds;
w_c = weight of material per car, in pounds;
μ = coefficient of friction.

Making $\mu = .01667$; $W = 1{,}500$ lb.; $w_c = 5{,}000 - 1{,}500 = 3{,}500$ lb.,

$$\tan a = \mu \frac{w_c}{2W + w_c} = .01667 \times \frac{3{,}500}{2 \times 1{,}500 + 3{,}500} = .00897;\ a = 0° 31', \text{ nearly.}$$

COST OF MINE ROADS

QUES. 2009.—Make an estimate of the probable cost of laying a double track in an entry 4,000 feet in length. Estimate the weight of the **T** iron as 16 pounds per yard and its cost $18 per ton; ties $.03 apiece, at the pit top; tracklayer to be paid at the rate of $2 per day, and all other labor required at the rate of $1.75 per day. *M.—Ill.*

ANS.—As few particulars are given, the following is an approximate estimate only of the actual cost: The weight of four lines of rails 4,000 ft. long is

$$\frac{4{,}000 \times 4 \times 16}{2{,}240 \times 3} = 38+ \text{ T.}$$

but the weight required to allow for cutting, making connections, and branches may increase this to 50 T.

50 T. of 16-lb. rails at $18 per T., delivered	$900
Cost of handling, lowering, and hauling to points in the mine where wanted	30
4,000 ties at $.03 apiece on the surface	120
Handling, lowering, and hauling ties	10
Frogs, crossings, and latches, number not known, but cost approximately estimated	50
2 tracklayers, 20 days at $2 each per day	80
7 assistant tracklayers, 20 days at $1.75 each per day	245
Alining and ballasting track, 20 days at $1.75 per day	35
Rock ballast 200 cu. yd. at $1 per yd.	200
Incidental expenses	100
	$1,770

SAFETY ARRANGEMENTS ON MINE ROADS

QUES. 2010.—What arrangements would you make on haulage roads for the safety of drivers and others? If employes are taken into the mine on the empty trips, hauled by electric motors or other mechanical means, what should be the speed of the trips?

I.—Pa. (*B*)

ANS.—The first question depends on the system of haulage adopted, number of drivers employed, etc. In mule haulage, strict regulations should be enforced in regard to the meeting places of drivers on single-track roadways and also in regard to the leaving of cars or trips in safe places where they cannot injure other drivers or become loose and run down grade. Where sprags are necessary, drivers must be cautioned not to descend a grade without seeing first that these are properly adjusted. Doors should not be permitted on haulage roads at or near the foot of a steep grade. Proper refuge holes should be provided at all doors requiring trappers, and at short intervals on all main haulage roads used as traveling ways.

Where employes are taken into the mine on empty trips hauled by electric motors or other mechanical means, the speed of the trip should not exceed 6 miles per hour.

QUES. 2011.—What are the requirements of the Bituminous Mine Law of Pennsylvania in regard to shelter holes on haulage roads? Also, state the requirements where sprags or brakes are used. *F.—Pa.* (*B*)

ANS.—Shelter holes shall be provided and kept whitewashed, and free from all obstructions, at distances not more than 30 yd. apart, on roads employing animal power; and not more than 15 yd. apart and at least 2 ft. 6 in. into the strata where hauling is done by machinery, and on gravity or inclined planes; provided, that shelter holes are not required on haulage roads where rooms are turned at regular intervals not exceeding 50 ft. apart, or where there is a space of 4 ft. between the wagon and the rib, where animal power is used, or 6 ft. where machinery is employed for haulage; and, provided, that this requirement shall not apply to parts of mines opened prior to the enactment of the Mine Law, if deemed impracticable by the mine inspector (Art. 6, Sec. 4).

Where road grades necessitate that sprags or brakes be applied or removed, there shall be a clear level width of not less than 2 ft. 6 in. between the side of car and the rib (Art. 20, Rule 3).

SIZE AND KIND OF MINE CARS

QUES. 2012.—How many cubic feet of space are there in a car $10\frac{1}{2}$ feet long, $4\frac{1}{2}$ feet wide, and 15 inches high? *F.—Pa.* (*A*)

ANS.— 15 in. = $1\frac{1}{4}$ ft.

$$10\tfrac{1}{2}\times4\tfrac{1}{2}\times1\tfrac{1}{4} = \frac{21}{2}\times\frac{9}{2}\times\frac{5}{4} = \frac{945}{16} = 59\tfrac{1}{16} \text{ cu. ft.}$$

QUES. 2013.—A mine car is 9 feet long, $4\frac{1}{2}$ feet wide, and 2 feet high; if 6 inches of topping is allowed, how many cubic feet of coal will the car carry? *F.—Pa.* (*A*)

ANS.—Assuming that the dimensions given are inside dimensions, the capacity of the car is

$$9\times4\tfrac{1}{2}\times2\tfrac{1}{2} = 101\tfrac{1}{4} \text{ cu. ft.}$$

QUES. 2014.—Two styles of mine car have the same general build and finish; they are equally good in appearance, but when well oiled and tested on an incline it is found that one starts to move at an inclination of 1 in 42, the other at an inclination of 1 in 49; which of these cars would you choose, and why? *M.—Ill.*

ANS.—I would choose the make of car that would run on a pitch of 1 in 49, because it takes less power to move this car than the other.

QUES. 2015.—A vein of coal 7 feet thick is opened by a shaft having two hoisting compartments, each 6 ft. 6 in. × 7 ft.; the roof is good and the bottom inclined to be soft: What gauge of track would you use? How would you build your main haulage road? Give the dimensions of the cars you would use. How much coal, mine run, should each car carry, broken coal weighing 70 pounds per cubic foot? *F.—Ind.*

ANS.—A track gauge of 3 ft. 2 in. may be used.

Level the roadbed to a uniform grade as far as practicable; lay ties 5 in. × 3 in. × 4 ft. 6 in. on the bottom, 2 ft. center to center; use 30-lb. rails and spike well to each tie; join the rails with fish-plates; if possible, drain all water off the road, aline the track, and ballast with rock or ashes; if the bottom is too soft for this, use corduroy.

Cars 5 ft. 6 in. long, 2 ft. 6 in. wide at the bottom, sides, 10 in. high straight up, then a 10-in. board set at such an angle that the car will be 3 ft. 6 in. wide at the top, and above that a 12-in. board. The dimensions given are outside dimensions. Use wheels 18 in. in diameter, and have the framework and running gear strongly built.

This car will contain 37 cu. ft., and will hold level full about 2,600 lb., or, with 12 in. of topping, about 4,000 lb.

NUMBER OF MINE CARS REQUIRED

QUES. 2016.—With an endless rope traveling 150 feet per minute in a mine working seventy-five places, and having four headings, a slope, and two slope air-courses going; supposing the mules on the headings can haul four cars per trip, and the slope mules one car per trip, one mule working in each heading, and two mules in the slopes; how many tram cars will you need to deliver 960 tons to the top in a working day of 8 hours; if you placed two cars on your rope at intervals of 150 feet, your haulage being 5,250 feet long, allowing a standing car for each working place and the necessary cars on the road and side tracks, and cars undergoing repairs? Answer fully, giving number of cars in each item. F_1.—*Ala.*

ANS.—Since the length of the haulage road is 5,250 ft., and trips of two cars each are run 150 ft. apart, $5,250 \div 150 = 35$ loaded and 35 empty trips or $2(35 \times 2) = 140$ cars in transit. There are in all eighty-two working places, including seventy-five rooms, four headings, a slope, and two air-courses; this will require eighty-two cars standing. Since a mule in each heading hauls four cars per trip, and the two slope mules haul one car each, the number of cars on the haulage roads will be $(4 \times 4) + 2 = 18$. Allow ten cars in the repair shop, and in order to avoid delay it will be necessary to allow for at least ten cars at the bottom and ten cars on the tipple landing. This will make the total number of cars

$$140 + 82 + 18 + 10 + 10 + 10 = 270 \text{ cars}$$

QUES. 2017.—How many tram ton cars would you require, and how many mules, in a drift with a grade that would warrant 3 ton-car trips, and a maximum haul of ½ mile, and a minimum of 600 feet to produce an output of 500 tons? *F.—Ala.*

ANS.—The average work of a mine mule under ordinary conditions of hauling may be stated to vary from 4 to 6 ton-miles per hour, and may be assumed in this case as 5 ton-miles per hour. For a maximum haul of ½ mile and a minimum haul of 600 ft., it may be assumed the average haul is

$$\frac{2,640 + 600}{2} = 1,620 \text{ ft.},$$

or about 1,600 ft. This is the length of the return haul, and it may be assumed that one half the time, or 5 hours, is consumed in hauling coal from the face to the parting where the trips are made up, the other half of the time being consumed in hauling the empty cars to the face and in making the change of cars. This will give for the total work required of the mules

$$\frac{500 \times 1,600}{5} = 160,000 \text{ T.-ft.},$$

or about 30 ton-miles per hour. To this must be added about 50 per cent. to allow for the dead weight of cars and friction, making the total work required 45 ton-miles per hour. The number of mules necessary for this work will then be $45 \div 5 = 9$ mules.

In order to estimate the number of cars required, allow two idle trips, loading at the face, and one trip in transit from the face to the tipple, making a total allowance of three trips of three cars each, for each mule. The total number of cars, adding 10 per cent. for cars out of repair and in use for other purposes, will then be

$$1.1 \times 9(3 \times 3) = 89 \text{ cars}$$

SYSTEMS OF HAULAGE

QUES. 2018.—What systems of haulage are in use in different states? *F_1.—Ala.*

ANS.—Mule haulage is common in smaller mines, and in the inside workings for gathering the cars or making up the trips and distributing the empties. The different forms of rope haulage, such as engine plane, gravity plane, tail-rope, and endless-rope haulage are also in use. Compressed air, electric, and steam locomotives are used to a limited extent.

QUES. 2019.—How many stages of underground haulage are there, and which should be the shorter? *F.—Ind.*

ANS.—Except in small mines, there are two stages of underground haulage. The first stage is the gathering stage in which the coal is moved from the face to the inside parting or side track at the inby end of the main haulage system. In the second stage, the coal is moved from the inside parting to the foot of the shaft or slope, or to the mine opening in a drift mine. The gathering stage should be always the shorter of the two.

QUES. 2020.—Name and describe briefly the different systems of mine haulage in use in the bituminous region, and state to what conditions each is best adapted. *F.—Pa. (B)*

ANS.—The several systems of mine haulage in use may be described as belonging to one of the two general classes of *Animal haulage* and *Mechanical haulage:* Mechanical haulage is again divided into *Rope haulage* and *Locomotive haulage.* Rope haulage includes gravity-plane haulage, engine-plane haulage, endless-rope haulage, and tail-rope haulage. Motor haulage embraces all forms of haulage by compressed-air, electric, steam, or gas locomotives. Mule haulage is adapted to small mines or the early development of larger mines, previous to the adoption of some form of mechanical haulage; also, to the gathering of the loaded cars from the face and hauling them to partings where trips are made up ready to be hauled out of the mine, and to the distribution of the empty cars as they arrive at the inside

parting. The several systems of rope haulage are adapted to conditions where it is not advisable to make the necessary outlay required for the establishment of a compressed-air or electric plant, or where other conditions render motor haulage impracticable or impossible. Gravity-plane haulage is adapted to inclines where the weight of the descending loads is used to draw up the empty cars. Engine-plane haulage is adapted to inclines where the loads must be moved up the plane, a winding engine being employed for the purpose, the empty cars drawing the rope after them down the plane. Endless-rope haulage is best adapted to level haulage or light, uniform grades where a double-track system can be employed by using two entries or a single wide entry, but is also employed on inclines. The tail-rope system of haulage is better adapted to light, variable grades, and may be used to advantage where the haulage roads are not particularly straight. Locomotive haulage is particularly adapted to large outputs and district haulage. Locomotive haulage may be advantageously employed upon short, steep, variable grades, and winding roads. Compressed-air locomotives possess the advantage of supplying fresh air to the workings and giving off no noxious gases. Electric locomotives possess the advantage of furnishing an extremely elastic and pliable system, but they introduce an element of danger arising from the presence of live wires in the mine workings. In gaseous mines, there is, besides, the danger of the possible ignition of bodies of firedamp. Steam locomotives have the disadvantage of the steam and noxious gases given off by the locomotive.

Ques. 2021.—What system of haulage would you consider best adapted for mines under the following conditions: When the haulage roads have an uneven grade? When there is a grade of 5 per cent. against the load? When the roads are fairly level? *F.—Pa. (B)*

Ans.—Tail-rope haulage is best adapted to varying grades.

A grade of 5 per cent. against the loads presents conditions favorable to engine-plane haulage.

Level roads offer either endless-rope or some form of locomotive haulage, preferably compressed-air or electric.

ANIMAL HAULAGE

Ques. 2022.—Describe the best method for hauling coal, by mules, out of a gangway 5,000 feet long, and the best grade for the track. *F.—Pa. (A)*

Ans.—The best method for haulage by mules, in this case, would be to provide partings or turnouts at suitable distances along the haulage road. This distance for a regular output of say from 500 to 800 T. per day may vary from 200 to 300 yd. in length. One or two drivers may be employed on each stretch, or between each of the consecutive partings. Two drivers are preferable since they can assist each other in case of difficulty arising

from the derailment of cars, etc., and where the grades are suitable they should follow each other instead of alternating trips. Where there are steep grades on the haulage road, however, the second driver should not follow the first too closely. The best grade for the haulage road is a slight grade in favor of the loaded cars. This grade should not exceed 3 per cent., and a 2-per-cent. grade is preferable.

QUES. 2023.—What is the economical limit of haul within which you would use mules, with a favorable grade, and what conditions would control this limit? *H.—Ia.*

ANS.—For the work of gathering cars at the face, the maximum distance a mule should haul should ordinarily not exceed 2,000 ft. from the face to the parting where the trip is made up. In many cases, this distance may, with advantage, be less, and the average distance for the best results should probably not exceed 600 to 1,000 ft. The condition that determines the distance of haul from the face to the parting where the trips are made up is the ability of the mules to haul the required quantity of coal to the parting as fast as it is hauled to the shaft bottom. No fixed rule can be given for the extent to which mules should be used on the main haulage, but unless the local conditions will not warrant the expense of mechanical haulage, mule haulage on the main haulage ways should not extend for more than ½ mile from the mine opening.

QUES. 2024.—When would you deem it advisable to replace mules with mechanical haulage? *F.—Ind.*

ANS.—Mule haulage should be replaced by some form of mechanical haulage when the development of the mine has progressed sufficiently so that the several districts of the mine will supply enough coal to keep the system running.

QUES. 2025.—What kind of haulage would you recommend in place of mules, and why? F_1.—*Ala.*

ANS.—Mule haulage should be replaced by rope haulage or by steam, compressed-air, or electric locomotives as early in the development of the mine as practicable, for the reason that, except for very small mines, rope or locomotive haulage is cheaper and much more efficient than mules, and does not vitiate the mine air as do mules, except in the case of a steam locomotive.

QUES. 2026.—If you had a tail-rope haulage in operation in your mine, how far would you consider it practicable to haul by animal power, knowing you had plenty of coal to develop? *F.—Pa. (B)*

ANS.—The question of mule haulage at the face is largely a question of cost of the maintenance of the temporary roads, and the ability of the

drivers to put the required amount of coal on the inside parting without causing any delay in making up the trips. Whenever the mule haulage becomes congested from too great a length of the temporary roads, it is necessary to extend the rope haulage to a point nearer the face in order to relieve the congestion. In general, it may be stated that the length of mule haulage at the face should not exceed 1,000 to 1,500 ft., and it is often preferable to reduce this.

MECHANICAL HAULAGE

QUES. 2027.—What experience, if any, have you had with mechanical underground haulage? If any, describe the same briefly. *F_1.—Ala.*

ANS.—Have had experience with underground gravity-plane, engine-plane, tail-rope, and endless-rope haulage systems. In the use of a gravity or inclined plane, the grade must be sufficient to enable the loads, when descending, to pull up the empties. The track may be double all the way, or single the upper half and double the lower half, or single all the way except for a short distance at the passing point. Gravity inclines are often used on inside main roads and on very steep rooms. The grade of an engine plane must be sufficient for the empties to run by gravity into the mine, pulling the rope after them, after which the engine pulls out the loads.

In tail-rope haulage, a single track is required. This system of haulage is better adapted to undulating grades and to curves in the track than the endless-rope system. Two drums are usually employed, which are loose on the drum shafts. One rope, known as the main rope, passes down the center of the track, supported on rollers, while the other, called the tail-rope, passes along the heading outside of the track to the inside parting where is located a tail-sheave or bull wheel, around which it passes, and then back in the center of the track and is attached to the rear end of the trip. The tail-rope pulls the empty trip in, dragging after it the main rope, which is attached to the other end of the trip, and which, in turn, pulls out the loaded trip. The trip thus makes the connecting link between the two ropes. Usually large trips are hauled at speeds approaching 1,000 ft. per min.

As the mine advances and the length of haul increases, the capacity of a tail-rope haulage system may not be equal to the required output of the mine, in which event, if other conditions permit, recourse may be had to the endless rope. This system requires a double track the entire length of the haul. The cars are attached singly, or two or more at a time, to the rope, which has a speed of about 150 ft. per min. In this system, as the cars are attached at regular intervals, the capacity is not affected by the length of the haulage. The rope may be carried in the center of the track, under the cars, or it may rest on suitable supports on the tops of the cars. In the latter case, at the various landings the rope is raised and placed in a sheave when it is desired to take off empties or put on loads, and this is done without stopping the rope. Carrying the rope on top of the cars

gives long life to rope, as it is practically supported all the way, but this system is not well adapted to haulage around curves, where it is generally necessary to let go of the rope and run around the curve by gravity, after which the rope is again gripped. By carrying the rope under the cars, curves can be operated without letting go of the rope, but there is then more or less complication at the switches.

Steam, compressed-air, and electric locomotives are also used for underground haulage. All three are well adapted for crooked roads, but they are not adapted to heavy grades. A steam locomotive gives great annoyance with the smoke from the coal used in firing, and hence the very best ventilation is required to rapidly free the workings from this nuisance. To overcome the smoke difficulty, and also the danger from gas explosions, compressed-air locomotives are often used, and some very successful plants are in operation. In electrical haulage, there is danger of sparks igniting the gas in gaseous mines.

QUES. 2028.—What, in your opinion, is the best system of mechanical haulage to suit all conditions? Give reasons.

F.—Pa. (*B*)

ANS.—This is purely a matter of opinion, since no one system of mechanical haulage is strictly suited to all conditions. Where electric haulage or compressed-air haulage has proved economical and advantageous in some mines, rope haulage has proved equally successful in other mines. In the operation of a large plant, and especially where punching machines are run with air at the working face, compressed-air motors may often be used for haulage to great advantage, and result in a saving of expense for equipment and operation, as the same plant will then furnish the power for both purposes. In some mines, however, where compressed air is used for the mining machines, electric haulage is used to advantage. The use of compressed air is advantageous in gaseous mines. The use of electricity possesses a great advantage in the flexibility of the system, as the wires conducting the current are easily installed and changed to suit the varying conditions in the mine. Both of these systems, however, require the installing of an expensive plant at the surface for compressing the air or generating the electricity. In this regard, rope haulage has the advantage; and inasmuch as some form of rope haulage can nearly always be installed, whatever the conditions in the mine with respect to the inclination of the seam, gas, character of roof and floor as affecting the security of the mine passages, this would seem to be the system that would best answer the question. The gaseous condition of the mine will often render the adoption of an electric system of haulage inadvisable. Highly inclined seams render haulage by electric or compressed-air motors impracticable, and for these reasons rope haulage is the only system of mechanical haulage that can be said to be adaptable to all conditions. It must be clearly understood, however, that although adaptable in nearly all cases, it is very often not the most economical or convenient system.

QUES. 2029.—How many classes of rope haulage are there? Name them. *F.—Ind.*

ANS.—There are four classes of rope haulage: gravity-plane haulage, engine-plane haulage, tail-rope haulage, and endless-rope haulage.

QUES. 2030.—Name the conditions under which the rope or motor haulage system would be preferable, the one to the other. *F.—Ind.*

ANS.—In general, rope haulage is adapted to long straight roads that may be flat or have considerable inclination. Motor haulage is preferable to rope haulage on level roads or roads of small inclination where there are numerous windings and irregularities in the roads, causing short variable grades and sharp curves in the tracks. Electric or compressed-air locomotives are often preferred to rope haulage, in mines where the same power is used for running mining machines at the working face.

ENDLESS-ROPE HAULAGE

QUES. 2031.—Describe in detail the endless-rope system. *F_1.—Ala.*

ANS.—The endless-rope system of haulage consists of one continuous rope, running from the drum into the mine and passing over a return sheave located at the farthest point within the mine and returning again to the engine. In this system, there are usually arrangements made for a double track to provide for the uninterrupted passage of the empty and loaded cars going in and coming out of the mine. The empty and loaded tracks may be both in the same entry, provided that the roof and floor are of such nature as to admit of a wide entry being driven that will accommodate double tracks, or the empty and loaded tracks may occupy separate entries. In some cases, a single track is used and side tracks or partings are arranged at intervals along the haulage road for the passing of the empty and loaded trips. This is not an advantageous arrangement. In the endless-rope system, the rope runs continuously in one direction. The rope passes two or three times around the driving drum and then back over a movable sheave arranged upon a balance car in such a manner as to take up the slack of the rope, and thence into the mine. This arrangement is necessary in order to compensate for the lengthening and shortening of the rope in this system. The friction of the coils of rope upon the drum is generally sufficient to equal at least the breaking strain of the rope, so that there is no danger of the rope slipping upon the drum. The drum over which the rope passes is not the same as the ordinary winding drum; but when a single drum is used, it is of the form of a large grooved pulley around which the rope passes two or three times. As the rope winds on to the pulley at one side it surges along the face of the pulley, gradually, until it reaches the

lowest position in the groove, and shortly after passes off from the pulley. This surging of the rope sidewise upon the face of the pulley is hard on the rope, causing it to wear out rapidly. To avoid this, two drums or pulleys are often used having three or four grooves on the face of each drum. The rope passes from the first groove on one drum to the first groove on the other drum, and then back to the second groove on the first drum, and thence to the second groove on the second drum, etc., making a half turn only on each drum, but accomplishing by this means the fleeting or surging of the rope sidewise without occasioning any wear of the rope. The cars, either singly or in trips, are attached to the rope by means of a friction clutch, which may be released at any moment by the trip rider.

When it is necessary to haul from several districts in the endless-rope system, this is sometimes accomplished by carrying the main rope, returning from the inside workings, around a deflecting sheave at the mouth of the district and so into the district in question, where it passes over a return sheave located near the face and returns to the main haulageway, where it again passes over a deflecting sheave and continues on its way out of the mine. A better method, however, of accomplishing district haulage is by causing the main rope to pass two or three times around a sheave at the mouth of the district, this sheave being used as a driving sheave for that district. When this is done, the haulage in each district is accomplished by a separate rope driven by a grooved pulley connected by suitable gearing with the driving sheave, which is driven by the main rope and located at the mouth of the district. This latter method possesses the advantage that the breaking of any district rope does not interfere with the haulage on the main road and the other districts, as would result in the use of the former method.

QUES. 2032.—Where would you place the tension car to take up the slack of the rope, in endless-rope haulage? Explain its arrangement. *F_1.—Ala.*

ANS.—The tension car for taking up the slack of the rope consists of a weighted truck carrying a horizontal sheave around which the rope passes. This truck usually runs on a short inclined track placed at the rear of the engine. Instead of being inclined, the track may be level and a suspended weight attached to a wire rope used to balance the pull on the truck. The running-off rope passes from the drum of the winding engine around the sheave on the truck and thence back into the mine.

QUES. 2033.—Where is the tail-sheave, or bull wheel, placed in a tail-rope haulage? *F_1.—Ala.*

ANS.—In a tail-rope haulage, the tail-sheave is placed at the inby end of the inner parting or side track where the trips are made up to be drawn from the mine.

HAULAGE CALCULATIONS

QUES. 2034.—What is the stress on the haulage rope in a slope pitching 40°, when the rope is hauling a load of 5 tons?

F.—Pa. (A)

ANS.—The gravity pull due to this load on this inclination is $(5 \times 2,000) \sin 40° = 10,000 \times .64279 = 6,428$ lb.

This rope when hauling the load up the slope is also subject to a friction pull equal to the perpendicular pressure of the load on the track $(10,000 \times \cos 40°)$ multiplied by the coefficient of rolling friction, which may be taken as .025, making the friction pull

$$.025(5 \times 2,000) \cos 40° = .025 \times 10,000 \times .76604 = 192 \text{ lb.}$$

in addition to the gravity pull due to the load. The total load on the rope is then

$$6,428 + 192 = 6,620 \text{ lb.}$$

There is also a stress due to bending where the rope passes around a sheave or winds on the drum.

QUES. 2035.—What pull on the rope will balance a trip on an incline, the fall of which is 1 in 13; the friction of wheels, rails, etc. being .01667?

I.—Ill.

ANS.—The sum of the gravity and friction pulls will give the approximate pull on the rope; the formula for expressing this pull is

$$T = W(\sin a + \mu \cos a)$$

in which T = pull on rope;
W = weight of trip;
a = angle of inclination of plane;
μ = coefficient of friction.

To find the angle of inclination, it may be assumed that the incline falls 1 ft. vertically in 13 ft. of horizontal distance; then $\tan a = \frac{1}{13} = .0769$; $a = 4° 24'$; $\sin a = .07692$; $\cos a = .99705$. Substituting the values in the formula

$$T = W(.07672 + .01667 \times .99705) = W(.07672 + .01662) = .09334W$$

That is, disregarding the weight of the rope, the pull due to the loaded trip, including gravity and friction, is .09334 times the load.

QUES. 2036.—What weight of motor will be required to haul four cars (gross weight 2 tons each) up a grade, assuming a coefficient of friction of .025, and a coefficient of traction of .16, the tangent of the angle of inclination being .03492?

I.—Ia.

ANS.—In this case, calling the weight of the motor W, the tractive force of the motor is $.16W$, and this must equal the gravity pull plus the friction pull of the entire moving weight. The weight of the loaded trip

is $4\times 2 = 8$ T., and the weight of the motor W, hence the entire moving weight is $W+8$. Then, indicating the angle of inclination by α,

$$.16W = (W+8)(\tan\alpha + .025);$$

and
$$W = 8\times\frac{.03492+.025}{.16-(.03492+.025)} = 4.79 \text{ T.}$$

Ques. 2037.—How much work is done in raising 300 tons of coal up an incline 2,700 feet long, and rising 1 foot in 3, when the friction of the cars adds 40 per cent. to the load? *I.—Ia.*

Ans.—If the plane rises 1 ft. in 3, the tangent of the angle of inclination is $\frac{1}{3} = .333+$, and the corresponding angle is about 18° 26′. Then the height through which the load is raised is

$2{,}700\times\sin 18° 26' = 2{,}700\times .3162+ = 853.74$ ft., approximately 854 ft.

Then, if the friction adds 40 per cent. to the load, the total load is

$$300\times 1.4 = 420 \text{ T.}$$

and the work done in raising this load 854 ft. is

$$W = 420\times 2{,}000\times 854 = 717{,}360{,}000 \text{ ft.-lb.}$$

Ques. 2038.—A single-track slope 500 feet long, dips at the rate of 25 per cent., what size of rope would you use, and what would be the horsepower of the engine required to deliver 1,200 tons of coal per day of 10 hours, allowing 40 per cent. of the time for changing trips? *I.—Pa. (A)*

Ans.—Allowing 40 per cent. of the time for changing cars leaves 60 per cent., or 6 hours for the actual time of hauling. An output of 1,200 T. in 6 hours is 200 T. per hour., and assuming fifty trips per hour makes 4 T. of coal hauled each trip. Using 1-T. cars there will be four cars weighing each, say 1,600 lb. The gross weight hauled per trip is then coal 8,000 lb., cars 6,400 lb., and weight or rope, say 600 lb., making the total moving load when the trip is at the foot of the slope 15,000 lb. For a 25-per-cent. grade, the gravity pull is $.25\times 15{,}000 = 3{,}750$ lb., and taking the coefficient of friction as $\frac{1}{50}$, the friction pull is $\frac{1}{50}\times 15{,}000 = 300$ lb., giving a total pull on the rope of $3{,}750+300 = 4{,}050$ lb., or about 2 T. The diameter of a six-strand seven-wire crucible-steel haulage rope necessary for this work is then, using a factor of safety of 10,

$$d = \sqrt{\frac{10\times 2}{37}} = .73, \text{ or about } \tfrac{3}{4} \text{ in.}$$

This rope will weigh .89 lb. per ft., making the total weight of rope a little less than 500 lb.

The length of haul being 500 ft., the speed of winding when making fifty trips per hour, is

$$\frac{2\times 500\times 50}{60} = 833 \text{ ft. per min.}$$

Since the total load on the rope, including friction, is 4,000 lb., the rated horsepower of the engine, assuming an efficiency of 60 per cent., is

$$H = \frac{4{,}000\times 833}{.6\times 33{,}000} = 168+ \text{ H. P.}$$

QUES. 2039.—A hauling engine draws coal up an incline 1,100 yards long, rising 1 in 5. In 6 hours continuous working, 500 tons of coal is raised, the conditions being as follows: System of hauling, endless rope; cars attached to rope in couples 20 yards apart, going in and coming out; full car weighs 10 hundredweight, empty car weighs $3\frac{1}{2}$ hundredweight; weight of rope $5\frac{1}{2}$ tons; weight of coupling chains 15 hundredweight; friction $\frac{1}{50}$ of load. What is the effective horsepower of engine required for the work? *M.—B. C., Canada*

ANS.—Let O = output, in pounds per minute;
v = speed of winding, in feet per minute;
l = length of haulage road, in feet;
c = weight of coal in each car, in pounds;
w_1 = weight of each car, in pounds;
w = weight of rope, including couplings, in pounds.

Then,

$$\frac{lO}{v} = \text{weight of coal in transit;}$$

$$\frac{2lO}{vc}\times w_1 = \text{weight of moving cars, loaded and empty;}$$

$$\frac{lO}{v}\left(1+\frac{2w_1}{c}\right)+w = \text{entire moving load}$$

Then, since the coefficient of friction in this case is $\frac{1}{50}$, the friction pull of this load is $\frac{1}{50}$ of the entire moving load. First calculate the speed of winding by dividing the output per minute by the weight of coal per lineal foot of rope. The output per minute is

$$O = \frac{500\times 2{,}000}{6\times 60} = 2{,}778+ \text{ lb. per min.}$$

The weight of coal per lineal foot of rope is found by dividing the capacity of two cars by 60, since there are two cars on the rope in every 20 yards; thus, since the capacity of each car is

$$c = (10-3.5)100 = 650 \text{ lb.},$$

$$\frac{2c}{60} = \frac{2\times 650}{60} = 21\tfrac{2}{3} \text{ lb.}$$

Hence, the speed of hauling is

$$v = 2{,}778 \div 21\tfrac{2}{3} = 128.2 \text{ ft. per min.}$$

The friction pull of the entire moving load is found by substituting the several values in the expression given for the entire moving load and dividing by 50; thus,

$$p_f = \frac{1}{50}\left[\frac{3\times 1{,}100\times 2{,}778}{128.2}\left(1+\frac{2\times 350}{650}\right)+(5.5\times 2{,}000+1{,}500)\right] = 3{,}220 \text{ lb.}$$

The horsepower absorbed by the friction of the load is therefore

$$\frac{3{,}220 \times 128.2}{33{,}000} = 12.5 \text{ H. P.}$$

Since the weight of the ascending cars and rope on the incline balances that of those descending, the only work performed owing to the incline is that due to elevating the coal through the vertical height of the incline, or

$$\frac{3 \times 1{,}100}{5} = 660 \text{ ft.}$$

and the horsepower for this purpose is

$$\frac{2{,}778 \times 660}{33{,}000} = 55.5 \text{ H. P.}$$

The total horsepower for this haulage is $12.5 + 55.5 = 68$ H. P.

Ques. 2040.—It is desired to hoist 500 mine cars on a double-track slope 900 feet long on an average pitch of 45°, two cars to be raised at once; weight of coal 3 tons to each car; weight of car $1\frac{3}{4}$ tons. Find the general dimensions of hoisting engines, diameter of drum, size of ropes, etc. you would recommend to perform this work. Steam pressure averages 85 pounds to the square inch.

I.—Pa. (A)

Ans.—As the time of hoisting is not given, a day of 10 working hours is assumed. If 500 cars are hoisted in 10 hr., 50 cars are hoisted in 1 hr.

$$50 \div 2 = 25 \text{ trips per hr.}; \; 60 \div 25 = 2\tfrac{2}{5} \text{ min. per trip}$$

If there is 1 min. delay each trip in changing cars, the actual time of each hoist is $2\frac{2}{5} - 1 = 1\frac{2}{5}$ min.

Weight of loaded car,

$$3 + 1\tfrac{3}{4} = 4\tfrac{3}{4} \text{ T.};$$

Weight of loaded trip,

$$2 \times 4\tfrac{3}{4} = 9\tfrac{1}{2} \text{ T.};$$

Weight of 1-in. rope,

$$900 \times 1.58 \div 2{,}000 = .711 \text{ T.};$$

Tension of loaded rope,

$$T = (9\tfrac{1}{2} + .711) \times \left(.707 + \frac{.707}{40}\right) = 7.454 \text{ T.}$$

The breaking strength of a 1-inch six-strand seven-wire extra strong crucible cast-steel hoisting rope is 37 T., and $37 \div 7.454 = 4.96$ as a factor of safety, or approximately 5, which is the factor used in the wire-rope tables published by the makers of wire rope. To find the maximum load on the engine, deduct from the tension found the pull of the descending trip on the other rope. This pull is found as follows:

Weight of 2 cars,

$$2 \times 1\tfrac{3}{4} = 3\tfrac{1}{2} \text{ T.}$$

Tension of empty rope,

$$T_1 = 3\tfrac{1}{2} \times \left(.707 \; \frac{.707}{40}\right) = 2.412 \text{ T.}$$

Hence, load on the engine is

$$7.454-2.412 = 5.042 \text{ T.}$$

In the use of a haulage rope of seven wires per strand, it is good practice to use a winding drum having a diameter sixty to eighty times the diameter of the rope; then, in this case, using eighty, the diameter of the drum is 80 in. The effective work per revolution of drum is

$$5.042\times 2{,}000\times 3.1416\times 6\tfrac{2}{3} = 211{,}200 \text{ ft.-lb., approximately}$$

Assuming that the hoisting engine has an efficiency of 85 per cent., then $211{,}200\div .85 = 248{,}470$ ft.-lb. is the total work per revolution. If the engine cuts off at $\frac{3}{4}$ stroke with an average boiler pressure of 85 lb., the M. E. P. in the cylinder will be 68.78 lb. Assume the engine to be geared 1 : 3; the length of stroke as $1\frac{1}{2}\times$diameter of cylinder (d), the load on the engine is $L = 5.042\times 2{,}000 = 10{,}000$ lb., approximately; diameter of drum $D = 80$ in.; ratio of strokes to diameter of cylinder $r = 1\frac{1}{2}$; ratio of gearing $r_1 = 3$; mean effective cylinder pressure $p = 68.78$ lb.; then

$$d = \sqrt{\frac{2\times 10{,}000\times 80}{68.78\times 1\frac{1}{2}\times 3}} = 17.29;$$

an 18-in. cylinder would be used. Hence, since the length of stroke is $l = r\,d = 1\frac{1}{2}\times 18 = 27$ in., the required size of second-motion duplex engine, geared 1 : 3 is 18 in. $\times$ 27 in.

Ques. 2041.—What power will be required to bring an output of 624 tons $\frac{3}{4}$ mile up a grade of 2 inches to the yard, from the inside turnout to the bottom, and to return the empty cars, which weigh one-half as much as the load carried in them, the resistance of the cars being $\frac{1}{70}$, and as much power being required to move the rope as to move the cars, the speed of the rope being 3 miles per hour, the length of the day 8 hours, and the cars moving four-fifths of the time? *M.—Ill.*

Ans.—Speed of winding,

$$\frac{3\times 5{,}280}{60} = 264 \text{ ft. per min.}$$

Length of haul,

$$\frac{3}{4}\times(5{,}280) = 3{,}960 \text{ ft.}$$

Running time per trip,

$$3{,}960\div 264 = 15 \text{ min.}$$

Total running time,

$$\frac{4}{5}\times(8\times 60) = 384 \text{ min.}$$

Trips per day,

$$384\div 15 = 25\tfrac{3}{5}, \text{ approximately } 26$$

Coal hauled per trip,

$$624\div 25 = 24 \text{ T.}$$

Weight of loaded trip,

$$24+\frac{1}{2}(24) = 36 \text{ T.}$$

Weight of empty trip,

$$24 \div 2 = 12 \text{ T.}$$

Tangent of angle of inclination,

$$2 \div 36 = .0555+$$

Angle of inclination is 3° 10′ approximately; sine of 3° 10′ is .0552. Since the sine and tangent of so small an angle are nearly equal, the tangent may be used in calculating the gravity pull, as the calculations are thus simplified, but it must be remembered that to be strictly correct the sine should be used. To find the size of rope required, calculate, approximately, the friction and gravity pulls of the loaded trip.

Friction pull of loaded trip.... $\frac{1}{70}\times(36\times 2{,}000) = 1{,}000$ lb., approximately

Gravity pull of loaded trip..... $\frac{2}{36}\times(36\times 2{,}000) = 4{,}000$ lb.

Total load on rope, exclusive of its own weight, 5,000 lb.

Size of Rope Required.—Multiplying the load on the rope by 2 to provide against shock, and using a factor of safety of 5, the strain on the rope is

$$\frac{5{,}000\times 2\times 5}{2{,}000} = 25 \text{ T.}$$

The breaking strain of a $\frac{7}{8}$-inch crucible cast-steel six-strand seven-wire rope is 24 T. The diameter of the rope may be calculated as follows:

Estimated load is

$$\frac{2\times 5{,}000}{2{,}000} = 5 \text{ T.}$$

Diameter of the rope is

$$d = \sqrt{\frac{5\times 5}{37}} = .82, \text{ or about } \tfrac{7}{8} \text{ in.}$$

To allow for the wear of the rope, a 1-in. rope of which the approximate breaking strength is 32 T. and weighing 1.58 lb. per ft. would be used.

Weight of Rope.— $1.58\times 3{,}960 = 6{,}256.8$ lb., approximately 6,300 lb. As the question does not state the kind of haulage employed, a double-track engine-plane haulage may be assumed in which the load on the engine is balanced by the gravity pull of the empty cars. Then,

Ascending load,

$$\underset{\text{Coal and Cars}}{(36\times 2{,}000)} + \underset{\text{Rope}}{6{,}300} = 78{,}300 \text{ lb.}$$

Descending load,

$$12\times 2{,}000 = 24{,}000 \text{ lb.}$$

Load on Engine.—

$$\underbrace{\frac{2}{36}\times(78{,}300-24{,}000)}_{\text{Unbalanced Gravity Pull}} + \underbrace{\frac{1}{70}\times(78{,}300+24{,}000)}_{\text{Friction Pull}} = 4{,}472+ \text{ lb.}$$

Power required,

$$\frac{4{,}472 \times 264}{33{,}000} = 35.776 \text{ H. P.}$$

or allowing an efficiency of .8 in the engine, the rated power of the engine should be $35.776 \div .8 = 44.72$ H. P.

PLACES OF REFUGE

QUES. 2042.—What does the Illinois Mine Law provide in reference to places of refuge on main haulage ways? *E.—Ill.*

ANS.—The Illinois Mine Law is as follows:

(*a*) *Engine Planes.*—On all single-track hauling roads wherever hauling is done by machinery, and on all gravity or inclined planes in mines, upon which the persons employed in the mine must travel on foot to and from their work, places of refuge must be cut in the side wall not less than 3 feet in depth and 4 feet wide, and not more than 20 yards apart, unless there is a clear space of at least 3 feet between the side of the car and the side of the road, which space shall be deemed sufficient for the safe passage of men.

(*b*) *Mule Roads.*—On all hauling roads or gangways on which the hauling is done by draft animals, or gangways whereon men have to pass to and from their work, places of refuge must be cut in the side wall at least 2½ feet deep, and not more than 20 yards apart; but such places shall not be required in entries from which rooms are driven at regular intervals not exceeding 20 yards, and wherever there is a clear space of 2½ feet between the car and the rib, such space shall be deemed sufficient for the safe passage of men.

All places of refuge must be kept clear of obstructions, and no material shall be stored nor allowed to accumulate therein

CHAPTER XXIII

HYDRAULICS AND PUMPING

HYDRAULICS

QUES. 2100.—How many gallons of water will a tank hold, the tank being 53 inches in diameter, and 9 feet 11 inches high? F_1.—*Ala.*

ANS.— 9 ft. 11 in. = 119 in. Then the capacity of the tank is

$$G = \frac{.7854 \times 53^2 \times 119}{231} = 1,136.5 \text{ gal.}$$

PRESSURE DUE TO VERTICAL WATER COLUMN

QUES. 2101.—A shaft 500 feet deep is full of water, what is the pressure per square inch and per square foot at the bottom of this shaft? *F.—Pa.* (*B*)

ANS.—The water pressure in this case is

$$500 \times .434 = 217 \text{ lb. per sq. in.;}$$

or,

$$500 \times 62.5 = 31,250 \text{ lb. per sq. ft.}$$

QUES. 2102.—The pump column in a shaft is 400 feet long, the pipe being 12 inches in diameter and full of water; find the total weight of water in tons of 2,000 pounds, also the pressure of the water in pounds per square inch, at base of column. *F.—Pa.* (*B*)

ANS.—The total weight of the water in the column is

$$400 \times .7854 \left(\frac{12}{12}\right)^2 \times \frac{62.5}{2,000} = 9.8175 \text{ T.}$$

The water pressure at the foot of the column is

$$400 \times .434 = 173.6 \text{ lb. per sq. in.}$$

QUES. 2103.—If a pump is located at the bottom of a shaft 300 feet deep, what is the pressure per square inch when the pump is in operation? F_1.—*Ala.*

Ans.—The pressure due to this head of water is $300 \times .434 = 130.2$ lb per sq. in. When the pump is working, besides the gravity head, which in this case is 300 ft., there is a head due to the friction of the water in the column pipe, which is usually estimated at from one-third to one-half of the actual head. Hence, the pressure against which the pump works is four-thirds to three-halves of the pressure due to the weight of the water.

PRESSURE DUE TO INCLINED WATER COLUMN

Ques. 2104.—What will be the pressure per square inch at the bottom of a column pipe, on a slope 450 feet long, pitching 42°?
F.—Pa. (A)

Ans.—Assuming the column pipe to be full of water. The pressure at the bottom of the pipe due to this weight of water is $(450 \times \sin 42°)\ .434 = (450 \times .66913)\ .434 = 130.68+$ lb. per sq. in.

Ques. 2105.—A pipe line in the slope of a mine has an area of 144 square inches and is 2,000 feet long; the slope is on a grade of 1 in 10; what is the pressure per square inch at the bottom of the pipe when it is full of water? *M.—B. C., Canada*

Ans.—The vertical fall of the slope is $2{,}000 \div 10 = 200$ ft. The pressure of the water at the bottom of the pipe is, then, $200 \times .434 = 86.8$ lb. per sq. in. The sectional area of the pipe (144 sq. in.) does not enter the solution of the problem in this case.

FLOW OF WATER THROUGH ORIFICE

Ques. 2106.—What theoretical quantity of water will be discharged from an orifice 1 foot square in 10 seconds at a depth of 20 feet? *I.—Pa. (B)*

Ans.—Assuming a vertical orifice in a thin plate, the theoretical quantity of water discharged under the conditions named, is

$$q = a\sqrt{2g\,h} = 1\sqrt{2 \times 32\ 16 \times 20} = 35.86 \text{ cu. ft. per sec.}$$

and for 10 sec., the quantity is

$$35.86 \times 10 \times 7.48 = 2{,}682 \text{ gal.}$$

FLOW OF WATER THROUGH DITCH

Ques. 2107.—If you have a ditch 2 feet wide, and 2 feet deep, running full of water, at a velocity of 15 feet per second; how many gallons of water per minute are passing? *F.—Pa. (B)*

ANS.—The theoretical amount, not allowing for friction, is

$$\frac{2\times2\times15\times60\times1{,}728}{231} = 26{,}930 \text{ gal. per min.}$$

QUES. 2108.—If the main ditch in a mine is 18 inches wide and 1 foot deep, and running full of water at a uniform velocity of 5 feet per second, how many gallons of water is the mine producing in 24 hours? *F.—Pa.* (*B*)

ANS.—The quantity of water, is

$$\frac{(18\times12)\ (5\times12)\ (60\times60\times24)}{231} = 4{,}847{,}376+ \text{ gal.}$$

QUES. 2109.—A mine is drained by natural means, and the ditch carrying off the water is 12 inches wide and 12 inches deep; the drain is full of water and the water has a velocity of 2 feet per second; how many gallons of water are passing per minute? *F.—Pa.* (*B*)

ANS.—The sectional area of the ditch is 1 sq. ft., and since 1 cu. ft. of water contains 7.48 gal., the volume of water flowing per minute is

$$1\times2\times60\times7.48 = 897.6 \text{ gal. per min.}$$

QUES. 2110.—What size of square ditch running full of water at a velocity of 5 feet per second will theoretically deliver 675 gallons per minute? *F.—Pa.* (*B*)

ANS.—Since the ditch is square, the depth of the water will be equal to the width of the ditch; and calling this depth of water or width of ditch x,

$$x = \sqrt{\frac{675\times231}{60\times5\times12}} = 6.58 \text{ in.}$$

FLOW OF WATER THROUGH PIPES

QUES. 2111.—How many 3-inch pipes will be required to run off as much water as one 12-inch pipe, all being of equal length? *I.—Ia.*

ANS.—Assuming the same head for all the pipes, the flow of water in each pipe is proportional to the square root of the fifth power of its diameter. Then, calling n the number of 3-in. pipes required to equal the flow of one 12-in. pipe, we have

$$n\sqrt{3^5} = \sqrt{12^5},$$

and

$$n = \sqrt{\left(\frac{12}{3}\right)^5} = \sqrt{4^5} = 32.$$

That is to say, thirty-two 3-in. pipes will be required to replace one 12-in. pipe under the same head.

QUES. 2112.—In developing a new field, a feeder of water was opened and a 2-inch pipe laid to carry it away. Shortly afterwards another feeder was opened and another 2-inch pipe laid, and so on, as the inflow of water increased, until there were four 2-inch pipes laid in one entry, when it was decided to replace these four pipes with one that would carry three times as much water as the four pipes, and use the 2-inch pipes at another point in the mine. What size of pipe would be required for this service?

M.—Ill.

ANS.—As the quantity of water to be provided for is three times the original quantity, the required pipe must have a capacity equal to that of $3 \times 4 = 12$ two-inch pipes; then, since for the same head or length of pipe the flow of water through a pipe is proportional to the square root of the fifth power of its diameter, if the diameter of the required pipe is x,

$$\sqrt{x^5} : \sqrt{2^5} = 12 : 1; \quad \sqrt{x^5} = 12\sqrt{2^5},$$

and
$$x = 2\sqrt[5]{12^2} = 2\sqrt[5]{144} = 5.4 \text{ in.}$$

QUES. 2113.—Would two 5-inch pipes or one 7-inch pipe give the best result in a discharge line 2,000 feet long? *F_1.—Ala.*

ANS.—Assuming that the pipe lines are subject to a constant head and are of equal length, the flow in each pipe will be proportional to $\sqrt{d^5}$, in which d is the diameter of the pipe. Then, if the flow in one 7-in. pipe is represented by q, and that in two 5-in. pipes by q_2,

$$q_1 : q_2 = \sqrt{7^5} : 2\sqrt{5^5}$$

That is to say, while there are 12,965 gal. of water flowing through the 7-in. pipe there would be 11,180 gal. of water discharged from the two 5-in. pipes under the same head, or for every 100 gal. passing through the 7-in. pipe 86 gal. will pass through the two 5-in. pipes. The amount of material in the one 7-in. pipe as compared with that in the two 5-in. pipes, estimating on a thickness to resist equal heads, and assuming the lengths of the pipes to be the same, will be as 49 : 50. So that the one 7-in. pipe will not only discharge more water per minute, under the same head, than two 5-in. pipes, but will also have the advantage with respect to economy of material, and particularly economy of labor in laying the pipes.

QUES. 2114.—How many 3-inch pipes will present a sectional area equal to that of one 12-inch pipe? All being of equal length, will this number of 3-inch pipes discharge more or less water in a given time than one 12-inch pipe, and why?

ANS.—Since the areas of pipes are to each other as the squares of their diameters, the area ratio is equal to the square of the diameter ratio, or $\left(\frac{3}{12}\right)^2 = \left(\frac{1}{4}\right)^2 = \left(\frac{1}{16}\right)$. That is to say, a 12-in. pipe has a sectional area

16 times as great as that of a 3-in. pipe; and therefore sixteen 3-in. pipes will have the same area as one 12-in. pipe.

For the same head and length, the flow of water through pipes is proportional to the square root of the fifth power of the diameter of the pipe, or the quantity ratio is equal to the square root of the fifth power of the diameter ratio. For the sake of comparison, assume a flow of 100 gal. per min. in the 12-in. pipe, and calling the flow in the sixteen 3-in. pipes x,

$$\frac{x}{100} = \frac{16\sqrt{3^5}}{\sqrt{12^5}} = 16\sqrt{\left(\frac{3}{12}\right)^5} = 16\sqrt{\frac{1}{4^5}} = .5$$

or,

$$x = 100 \times .5 = 50 \text{ gal.}$$

That is to say, for every 100 gal. flowing in the 12-in. pipe, there would be but 50 gal. flowing in the sixteen 3-in. pipes of the same length and having the same head.

Ques. 2115.—We are using nine 2-inch pipes leading to nine sumps. We are going to gather all our water into one sump, and want to use one pipe to do the work. What size pipe will be necessary to replace the nine 2-inch pipes? *M.—Ill.*

Ans.—Assuming that the head causing the flow of water is the same in all the pipes and remains constant, and the lengths of all the pipes are equal, since the flow of water in the large pipe is nine times the water flowing in one small pipe, if the required diameter of the large pipe is x, the ratio of the diameter of the large pipe to that of the small pipe is $\frac{x}{2}$, and the ratio of the quantities flowing in these pipes is $\frac{9}{1}$. But for the same head and length of pipe, the fifth power of the ratio between the diameters of the pipes is equal to the square of the ratio between the quantities flowing through the pipes, and

$$\left(\frac{x}{2}\right)^5 = \left(\frac{9}{1}\right)^2;$$

or,

$$x = 2\sqrt[5]{9^2} = 4.8+ \text{ say } 5 \text{ in.}$$

One 5-in. pipe will therefore accommodate the same flow as nine 2-in. pipes of the same length and head.

ACTION OF A PUMP

Ques. 2116.—Why does a pump lift water? *F_1.—Ala.*

Ans.—There are pumps so constructed as to lift all the water above the piston, but we understand the question as referring to the suction of a pump, and why the water rises in the suction pipe of the pump when the piston is operated. The operation of the pump creates more or less of a vacuum behind its piston, and the pressure of the atmosphere upon the water in the sump forces the water up the suction pipe and into the pump because the vacuum in the pump leaves the atmospheric pressure only partly balanced.

HEIGHT OF SUCTION

Ques. 2117.—How far would you place a pump above the water it is to raise, expecting it to do effective work? *M.—Ill.*

Ans.—The distance that a pump will draw or lift water, or the theoretical height of the pump above the level of the water in the sump, depends on the atmospheric pressure upon the surface of the water, since it is this pressure that forces the water up the suction pipe and into the pump. The theoretical height to which the atmospheric pressure will force water at sea level, under normal conditions, is $14.7 \div .434 = 34$ ft., nearly. There are two causes that will reduce this theoretical height to which a pump will lift water: (1) The atmospheric pressure is not always 14.7 lb. per sq. in., but decreases as we rise above sea level. As a result, a pump at a higher elevation than sea level will not possess the same lifting power as at sea level. (2) Every pump is more or less imperfect, and it is not possible to produce a perfect vacuum behind the piston of a pump. For this reason, there is a back pressure, which would be shown by a vacuum gauge on the pump. This back pressure opposes the atmospheric pressure, and, in consequence, reduces the lifting power of the pump. These two causes operate together to reduce the effective height an ordinary pump will lift water, at sea level, to about 25 ft. If a pump is run at a moderately high rate of speed, this lift should be still further reduced in order not to impair the effectiveness of the pump. Always, the smaller the lift of the pump, the more effective will its work be.

Ques. 2118.—What maximum height should there be between a pump and the surface of the water in the sump, the barometer being 30 inches? *F.—Pa. (A)*

Ans.—A convenient rule is to take eight-tenths of the height of the barometer in inches as the height in feet, to which a pump will lift water. Thus, for a barometer of 30 in., $30 \times .8 = 24$ ft. This height may be increased or decreased slightly, according to the position of the suction pipe and its length. The perfectness of the pump also determines, to a certain extent, the height that the pump will draw. With the most perfect pump and a short vertical lift, this height will rarely exceed or even equal 28 ft. when the barometric height is 30 in.

Ques. 2119.—Is the vertical distance that a pump will draw water affected by its elevation above tide water, and why? *F_1.—Ala.*

Ans.—Yes, the vertical distance that the pump will draw water decreases as we rise above tide water, because the atmospheric pressure decreases.

WORK AND SIZE OF A PUMP

QUES. 2120.—What is the back pressure per square inch on the plunger of a pump that is raising water 175 feet? What mean effective steam pressure will be necessary to do this work, if the steam cylinder is 6 inches in diameter and the water cylinder 4 inches in diameter, making no allowance for friction? *H.—Ind.*

ANS.—Disregarding friction, the pressure on the plunger due to the weight of water in the column pipe, is

$$175 \times .434 = 75.95, \text{ say } 76 \text{ lb. per sq. in.}$$

Assuming an efficiency of 85 per cent. on the water end and 75 per cent. on the steam end of the pump, and calling the required steam pressure x, since the pressure per square inch in each cylinder is inversely as the areas of the cylinders or inversely as the squares of their diameters,

$$\frac{.75\,x}{.85 \times 76} = \left(\frac{4}{6}\right)^2,$$

and

$$x = 76\,\frac{.85}{.75}\left(\frac{2}{3}\right)^2 = 38.28 \text{ lb. per sq. in.}$$

QUES. 2121.—In pumping from a shaft 300 feet deep, with a steam pressure of 60 pounds at the shaft bottom, what should be the diameter of the steam end, if the diameter of the water end is 10 inches? *F_1.—Ala.*

ANS.—Assuming that the friction of the flow increases this head from 300 ft. to 310 ft. of water column, the pressure against which the pump will have to work is $310 \times .434 = 134.54$, say 135 lb. per sq. in.

Then, assuming an efficiency of 85 per cent. on the water end and 75 per cent. on the steam end of the pump, the effective pressure ratio is

$$\frac{.75 \times 60}{.85 \times 135} = \frac{20}{51};$$

and this is equal to the square of the inverse diameter ratio. Hence, calling the required diameter of the steam end x, we have

$$\left(\frac{10}{x}\right)^2 = \frac{20}{51},$$

and

$$x = 10\sqrt{\frac{51}{20}} = 10\sqrt{2.55} = 16 \text{ in. nearly}$$

QUES. 2122.—What horsepower will be required to drive a double-acting steam pump, if the vertical distance between the point of discharge and the point of suction is 150 feet? The diameter of the pump cylinder is 9 inches, the stroke 12 inches, and the number of strokes per minute 80. Add 25 per cent. for friction. *I.—Ia.*

ANS.— Pressure is $150\times.434 = 65.1$ lb. per sq. in.;
Friction is $65.1 \times.25 = 16.3$ lb. per sq. in.;

Total pressure 81.4 lb. per sq. in.

Area of pump cylinder a is

$$.7854\times 9^2 = 63.617 \text{ sq. in.}$$

Piston speed S is

$$\frac{12\times 80}{12} = 80 \text{ ft. per min.}$$

Then, for the total horsepower,

$$H = \frac{81.4\times 63.617\times 80}{33{,}000} = 12.55+ \text{ H. P.}$$

QUES. 2123.—In what time can an engine of 40 effective horsepower pump 4,000 cubic feet of water from a depth of 360 feet? *I.—Ia*

ANS.—The total effective work to be performed is $4{,}000\times 62.5\times 360 = 90{,}000{,}000$ ft.-lb. Each horsepower equals 33,000 ft.-lb. per min. and since 40 H. P. is effective for the performance of this work, the required time is,

$$\frac{90{,}000{,}000}{40\times 33{,}000} = 68.18 \text{ min.}$$

QUES. 2124.—If you had a pump 14 inches in diameter, 36-inch stroke, and having a 10-inch suction line 1,200 feet long and a vertical lift of 24 feet, what results would you expect, and how would you proceed to better the conditions without removing the pump?

ANS.—The atmospheric pressure acting on the surface of the water in the sump forces the water up the suction pipe and into the pump. Assuming the pump to be located at sea level, the atmospheric pressure under normal conditions is 14.7 lb. per sq. in., corresponding to a head of water $14.7\div.434 = 34$ ft., nearly. Since the vertical lift of the pump in this case is 24 ft., the effective water column available for forcing the water up to the pump is $34-24 = 10$ ft. This is still further reduced by the inability of the pump to produce a perfect vacuum owing to the escape of air from the water, and the leakage of air through the joints of the pipe and pump connections; it is a good pump that will produce and maintain a vacuum gauge of 24 in. of mercury corresponding to a water column of, say 27 ft., leaving, in this case, only $27-24 = 3$ ft. of effective water column available for forcing the water up the suction pipe and into the pump. This would be insufficient to supply the water that should be handled by this pump, even when running the pump at a very low speed. The proper remedy to apply will be to move the pump to a point nearer the sump. If this cannot be done, the only practicable recourse remaining is to place a small pump at the lower sump and force the water up to the pump, discharging it into a basin prepared at that point to receive it.

QUES. 2125.—We have a sump full of water, in a mine; the sump is 65 feet long, 8.5 feet wide, and 5.7 feet deep; the shaft is 525 feet deep; the resistance of the pump and column pipe is 12.5 per cent. How many horsepower will it take to empty this sump in 3 hours? *M.—Ill.*

ANS.—The weight of water to be hoisted is

$$65 \times 8.5 \times 5.7 \times 62.5 = 196,827+, \text{ say } 197,000 \text{ lb.}$$

The horsepower required to hoist this weight in 3 hours through a vertical height of $525+10 = 535$ ft., adding 10 ft. for depth of sump and clearance at top of shaft, and adding 12.5 per cent. for resistance of pump and pipe, is

$$H = \frac{197,000 \times 535 \times 1.125}{33,000 \times 3 \times 60} = 19.97+ \text{ H. P.}$$

QUES. 2126.—In a coal mine, the slope of which is 900 feet in length and has an average pitch of 30°, the quantity of water accumulating is 250,000 gallons per day. Give the size of pumps and the required speed of the same to remove this water by pumping 8 hours a day. *I.—Pa. (A)*

ANS.— 250,000 gal. in 8 hrs.

$$\frac{250,000}{8 \times 60} = 521 \text{ gal. per min.}$$

To this, we must add one-fourth for slip of water past the piston of the pump, making $521 \times \frac{5}{4} = 651$ gal. per min. Using a duplex double-acting pump, making twenty double strokes per minute, working at a speed of pumping of 80 ft. per min. for this lift,

$$\frac{651 \times 231}{2 \times 80 \times 12} = 78.32 \text{ sq. in., area of each water cylinder,}$$

and $$\sqrt{\frac{78.32}{.7854}} = \text{say } 10 \text{ in., diameter of each water cylinder}$$

Head $= 900$ ft. $\times \sin 30° = 900 \times .5 = 450$ ft. vertical lift. Allowing one-half of the power for frictional losses, and a mean effective steam pressure of 50 lb. per sq. in., the pumps being located at the bottom of the slope, the diameter of each steam cylinder is

$$d = 3.76\sqrt{\frac{Gh}{2(pS)}} = 3.76\sqrt{\frac{521 \times 450}{2 \times 50 \times 80}} = 20+ \text{ in.}$$

in which
d = diameter of cylinder, inches;
G = gallons per minute;
h = head, in feet;
p = steam pressure, pounds per sq. in.;
S = piston speed of pump, feet.

Hence, the size of duplex, double-acting pump is as follows: steam cylinder, 20 in. $\times$ 24 in.; water cylinder, 10 in. $\times$ 24 in.

DISCHARGE OF PUMP

QUES. 2127.—If you had a double-acting pump running at a piston speed of 90 feet per minute, the diameter of the plunger being 10 inches, how much water per hour would it discharge, and what should be the sizes of the suction and discharge pipes to allow this pump to work at its best? *F.—Pa. (B)*

ANS.—Assuming an efficiency of 85 per cent. for the water end of the pump, we have for the quantity of water discharged per minute

$$G = \frac{.85(.7854 \times 10^2 \times 90 \times 12)}{231} = 312 \text{ gal.}$$

To obtain the diameter of the suction and discharge pipes for a pump, it is customary to estimate on a velocity of 200 ft. per min. in the suction pipe and 400 ft. per min. in the delivery pipe. Then, we have,

suction pipe, $$d = 4.95\sqrt{\frac{G}{v}} = 4.95\sqrt{\frac{312}{200}} = 6+ \text{ in.}$$

Likewise, for the discharge pipe

$$d = 4.95\sqrt{\frac{G}{v}} = 4.95\sqrt{\frac{312}{400}} = 4+ \text{ in.}$$

QUES. 2128.—How much water will be discharged by a pump having a water end 10 inches in diameter, a 4-foot stroke, and making 48 strokes per minute? *F_1.—Ala.*

ANS.—The theoretical discharge of this pump is

$$\frac{.7854 \times 10^2 \times 4 \times 12 \times 48}{231} = 783 \text{ gal. per min.}$$

There is, however, always a certain amount of water that slips past the piston of the pump; on this account, it is customary to allow a certain efficiency for the water end, and assuming this to be 85 per cent. of the theoretical discharge, the amount of water actually discharged by this pump will be

$$783 \times .85 = 665+ \text{ gal. per min.}$$

QUES. 2129.—What quantity of water will a double-acting pump deliver, if the plunger of the pump is 4 inches in diameter and the piston speed 100 feet per minute? If the ratio between the diameter of the plunger and the diameter of the piston of this pump is 1 : 2, what steam pressure will be required in the cylinder of the pump to lift the water 300 feet? *I.—Pa. (B)*

ANS.—Assuming an efficiency of the water end of 85 per cent. and of the steam end 75 per cent., the quantity of water discharged by the pump may be found by the formula

$$G = .03468\, d^2 S = .03468 \times 4^2 \times 100 = 55.48+ \text{ gal. per min.}$$

in which G = gallons per minute;
d = diameter of piston, in inches;
S = piston speed in feet, per minute.

Assuming, as is customary, an efficiency of 75 per cent. for the steam end and 85 per cent. for the water end,

$$.75\, p\, D^2 = .85\, (.434\, h)\, d^2$$

in which D = diameter of steam cylinder;
h = head, in feet;
p = steam pressure;

or

$$\frac{.75\, p}{.85\, (.434\, h)} = \left(\frac{d}{D}\right)^2$$

That is to say, the ratio between the effective pressures upon the steam and water ends is equal to the square of the inverse ratio of the respective diameters. Assuming a friction head of 30 ft. the total head against which the pump works is $h = 330$. The required steam pressure is

$$p = \frac{.85 \times .434 \times 330}{.75 \times 2^2} = 40.579 \text{ lb. per sq. in.}$$

Ques. 2130.—What is the probable discharge of a duplex double-acting mine pump whose plungers are 10 inches in diameter and stroke 24 inches, when making 40 revolutions per minute? *I.—Pa. (A)*

Ans.—Assuming an efficiency of 85 per cent. at the water end of the pump, the equation expressing the capacity of the pump is,

$$G = \frac{.85\, (.7854\, d^2 S)}{231} = .03468\, d^2 S$$

in which G = water discharged, in gallons per minute;
d = diameter of plunger, in inches;
S = piston speed, in feet per minute.

For the piston speed of this pump,

$$S = \frac{40\, (2 \times 24)}{12} = 160 \text{ ft. per min.}$$

Substituting the given values in the equation, and multiplying by 2, the discharge of this duplex double-acting pump is,

$$G = 2\, (.03468 \times 10^2 \times 160) = 1,109.76 \text{ gal per. min.}$$

PUMP PARTS

Ques. 2131.—If a pump requires a 1½-inch steam line, and a 2-inch is just as convenient to use, would you use it, and would there be any advantage in it? *F_1.—Ala.*

Ans.—The 2-in. steam line will present less resistance to the flow and will give a higher cylinder pressure for the same boiler pressure. Therefore,

if the 2-in. pipe is at hand, and as convenient to use as the $1\frac{1}{2}$-in. pipe required, it will be generally considered preferable to use the 2-in. pipe.

QUES. 2132.—If you were putting a large pump in a mine, would you put in large valves or a number of small ones of the same area? State your reasons? *M.—Ill.*

ANS.—A sufficient number of small valves are more efficient in a mine pump than one large valve having an area equal to the total area of the small valves. The reason for this is that for the same lift of the valve a number of small valves furnish a larger area of discharge than a single large valve. These valves act, therefore, more promptly, and being distributed over a greater area of the valve seat furnish less obstruction to the discharge from the pump. The valves can also be made much lighter for the same strength, and are adapted to working under great pressures. The cost and trouble of repairing a small valve is also smaller than for a large valve.

QUES. 2133.—How would you install gasoline and electric pumps in a mine so as to prevent them from setting fire to the coal or timber? What instructions would you give to the attendant? *F.—Pa. (B)*

ANS.—The pump house should be built of masonry or other incombustible material, and ventilated, if possible, by a separate split of fresh air taken from the main intake and discharged at once into the main return airway.

The attendant should be instructed not to allow any accumulation of oil or waste in the pump room, to keep the pumps clean, and to examine carefully and regularly all electric and gasoline connections.

DRAINING A SUMP

QUES. 2134.—Suppose that a sump 12 feet in diameter and 25 feet deep, full of water, has an inflow amounting to 20 gallons per minute. How long will it take a pump having a 7-inch water end, a 14-inch stroke, and making 75 double strokes per minute, to empty the sump, the efficiency of the pump being only 72 per cent.? *M.—Ill.*

ANS.—The number of gallons of water in the sump is

$$12^2 \times .7854 \times 25 \times \frac{1{,}728}{231} = 21{,}150.7 \text{ gal.}$$

The discharge of this pump is

$$G = \frac{.72\ (.7854 \times 7^2) \times 2\ (75 \times 14)}{231} = 251.9 \text{ gal. per min., nearly}$$

The feeder running into the sump is 20 gal. per min., and, after discharging a quantity equal to the feeder, the pump has a capacity available for emptying the sump of $251.9 - 20 = 231.9$ gal., the sump will therefore be drained in

$$21,150.7 \div 231.9 = 91+ \text{ min., or 1 hr. 31 min.}$$

QUES. 2135.—A sump in a mine is 60 feet long and 6.5 feet deep; 30 feet of the sump is 6 feet wide, and 30 feet is 8 feet wide, and it is full of water. How long will it take a 6-inch pump, having a piston speed of 100 feet per minute, to empty this sump, allowing 20 per cent. for loss or slippage of water past the piston? How many horsepower will be required to empty the sump in 1 hour and 25 minutes, the shaft being 250 feet deep? *M.—Ill.*

ANS.—The capacity of this sump is

$$6.5\,(30 \times 6 + 30 \times 8) = 2{,}730 \text{ cu. ft.}$$

The piston displacement of a 6-in. pump running at a speed of 100 ft. per min. is

$$\frac{100\,(.7854 \times 6^2)}{144} = 19.635 \text{ cu. ft. per min.}$$

Allowing for a loss of 20 per cent. due to the slippage of water past the piston and the leakage of valves, the quantity of water pumped is $100 - 20 = 80$ per cent. of the piston displacement, or $19.635 \times .80 = 15.708$ cu. ft. per min. The time required for this pump to empty the sump when full of water will be, therefore, $2{,}730 \div 15.708 = 174$ min., or 2 hr. 54 min.

To calculate the power required to empty this sump in 1 hr. and 25 min. (85 min.), the shaft being 250 ft. deep, 10 ft. should be added for the suction lift reaching to the bottom of the sump, making the total lift $250 + 10 = 260$ ft.; the discharge is

$$\frac{2{,}730 \times 1{,}728}{85 \times 231} = 240+ \text{ gal. per min.}$$

Then, assuming an efficiency of 75 per cent. for the steam end of the pump, the horsepower required is

$$H = \left(\frac{62.5 \times 231}{.75 \times 33{,}000 \times 1{,}728}\right) G\,h = .00034\,G\,h = .00034 \times 240 \times 260$$
$$= 21.21 + \text{ H. P.}$$

QUES. 2136.—We have in a mine a sump 62 feet long, 8 feet wide, and 7 feet deep, that is full of water. How long will it take a 6-inch pump to empty this sump, the piston speed being 100 feet per minute, the resistance and leakage of valve being 10 per cent.? We have nine 2-inch pipes running full of water into the sump, at a velocity of 100 feet per minute. *M.—Ill.*

ANS.—There is more water flowing into the sump through the nine 2-in. pipes when running full at a velocity of 100 ft. per min., than is taken

out by a 6-in. pump at a velocity of 100 ft. per min. Since the areas are proportional to the squares of the diameters, the sectional area of the 6-in. pump is nine times the area of a 2-in. pipe $\left(\frac{6}{2}\right)^2 = 9$. Hence, the combined area of the nine pipes is equal to the area of the pump, and the velocity is the same in each; but owing to the 10-per-cent. loss by leakage in the pump, the discharge of the pump in this case is only nine-tenths of the discharge from the pipes.

MINE DRAINAGE

QUES. 2137.—Under what conditions would it be advisable to hoist water from a mine by means of a tank, in preference to pumping? *F.—Ind.*

ANS.—In general, at small mines where the amount of water to be handled is small, and the steam power is not more than is required for the hoisting engine; or where horsepower is employed for hoisting and no steam is at hand. At larger mines where the amount of water is small, and the output is such as can be readily hoisted in the allotted time, a tank swung below the cage is often employed for hoisting the water, since the emptying of the tank will not materially delay the hoisting. Water is also often hoisted in such tanks only at night and during the noon hour. By this means, the expense of installing, operating, and repairing a pumping plant is obviated, and the annoyance of steam in the hoisting shaft, incident to pumping, is avoided. Tanks are particularly serviceable when the water is very corrosive and there are now a number of plants where the entire use of a shaft is for the purpose of hoisting water by means of tanks. Tanks are particularly adapted for handling large volumes of water quickly in locations where fuel is cheap.

QUES. 2138.—In the development of a mine, it is found when the main entries have reached a distance of $\frac{3}{4}$ mile, that the amount of water has so increased that it is necessary to install a pumping plant capable of handling not less than 150 gallons per minute; how would you propose to do this? *M.—Ill.*

ANS.—A sump should be made in the mine at such a point as will afford the best drainage for the mine workings. A suitable pumping plant should be installed on the surface above the sump and a drill hole sunk to the sump, through which the water can be pumped. If the coal seam is too deep or other conditions prevent the location of a drill hole above or near the sump located away from the shaft the water may be pumped to the sump at the bottom of the shaft by a small pump and then pumped up the shaft by a large pump.

QUES. 2139.—Give the various methods of mine drainage, and state under what conditions each is most advantageous.
I.—Pa. (*A*)

ANS.—As far as practicable, the water from different portions of the mine should be drained to the foot of the slope or shaft, or to some other low point in the mine from which it may be conveniently lifted to the surface. The drainage to such point, as far as possible, is accomplished by gravity. Where this would require an amount of ditching that is impracticable, a siphon may often be employed advantageously to convey the water from one small basin to another lower basin. Where it is impracticable to drain all the water of the mine to a central sump or basin, local sumps may be excavated at convenient points in the mine, which may be drained by bailing or pumping according to the amount of water. Such local sumps or basins are often conveniently reached by a drill hole from the surface, and drained by a pump located generally on the surface. The main pumps for draining the mine are usually located at the foot of the shaft. Another convenient method of handling large quantities of water in deep shafts is that in which the water is hoisted to the surface in large tanks especially constructed for the purpose; under certain conditions this method has proved the most efficient and economical method that can be adopted. In an inclined seam worked in different lifts, it frequently happens that the greater part of the water comes from the upper lifts and the lower lifts are dry. The water should be caught at the highest possible place along the shaft or slope and pumped from there to the surface, and not allowed to go to the bottom, necessitating its being raised through a much greater distance.

SIPHONS

QUES. 2140.—What is the principle of the siphon, and to what height above the upper or supply basin can it raise water? How would you start the flow in a siphon? *F.—Ia.*

ANS.—A siphon is a bent tube or pipe, Fig. 1, having two legs of unequal length. If filled with water, and the two ends each immersed in a basin of water or sump, as shown in the figure, the weight of the atmosphere pressing on the surface of the water in each basin will support a column of water in each leg, whose weight is equal to that of an air column of equal sectional area.

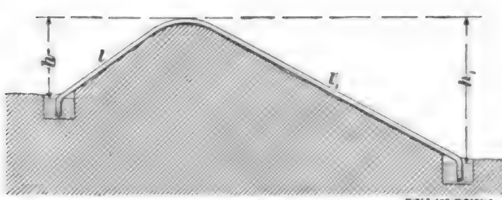

FIG. 1

Since the pressure of the atmosphere at sea level is 2,116.2 lb. per sq. ft., and the weight of 1 cu. ft. of water is 62.5 lb. nearly, the theoretical height

of water column supported by the atmosphere at sea level is $2{,}116.2 \div 62.5 = 34$ ft., nearly. In practice, the vertical height of the crown or highest point of the siphon, above the surface of the water in the upper basin, should not exceed 26 to 28 ft., according to the inclination and length of the pipe, being less for a long, flat pipe. For successful work, the difference of pressure between the two ends of the siphon must bear a certain relation to the size and length of the pipe or the resistance of the flow.

To start the siphon, both ends must be temporarily plugged or provided with stop-cocks that are closed. The pipe is then filled full to the crown by pouring water into it at this highest point. In doing this, care should be taken to pour the water in slowly, so as to give the air an opportunity to escape from the pipe. The stop-cock at this point is then closed, and both ends of the siphon being completely submerged in their respective basins, the stop-cock at the upper basin is opened first and then that at the lower basin, or both may be opened together, when the water will start to flow through the pipe if the latter is air-tight. It is important to control a too rapid flow of the water by partly closing the lower valve when there is a tendency of the pipe to empty itself.

QUES. 2141.—What conditions are required for the successful operation of a siphon? *F.—Pa. (A)*

ANS.—The height of the summit of the siphon above the surface of the water in the upper basin, or the vertical lift of the siphon, must not exceed a practical limit to which the atmosphere will force the water; this height theoretically is about 34 ft. at sea level, and decreases as we ascend above the level of the sea. A safe rule to apply in determining the vertical height to which the atmosphere will force the water in the suction pipe of a pump, or in the short leg of a siphon, is to take eight-tenths of the barometric height, in inches, for the vertical lift of the pump or siphon, in feet. Thus, if the barometer stands at 30 in., the lift of the pump or siphon may be taken as $30 \times .8 = 24$ ft. Where the suction pipe is nearly vertical and consequently of shorter length, this height may be somewhat increased; but where the suction pipe is inclined and its length therefore considerable, the vertical lift should be decreased proportionately.

The longer leg, or the discharge pipe of the siphon, must fall through a greater vertical height than the short leg or draft pipe. In Fig. 1, the vertical height h is called the lift, and the vertical height h_1 the fall of the siphon. The difference between these heights $(h_1 - h)$ may be called the siphon head. When the fall of the siphon h_1 exceeds the practical limit to which the atmosphere will force the water, care must be taken to arrange the fall of the siphon relative to its lift, so as to overcome the tendency to the formation of a vacuum at the crown of the siphon, which will cut off entirely, or reduce, the flow of water in the siphon. The formula

$$h_1 = \frac{l_1}{l}(34 - h) + 34$$

gives the proper fall h_1 for any lift h and lengths of pipe l and l_1. Both ends of the siphon pipe must be submerged to prevent air being drawn

into the pipe, and reaching the crown or summit of the siphon. This takes place more readily in the short leg of the siphon than it does in the long leg, due to the direction of the flow of the water. The submergence of the discharge end of the siphon, however, is important in order to insure a full flow in the pipe. Air that is carried into a siphon by the water will gradually accumulate at the highest point of the siphon pipe and will interfere with the working unless a cock is provided at that point through which the air can be let off from time to time.

QUES. 2142.—There is a shaft 50 feet deep on a hillside, and 500 feet away is a creek, 100 feet below the level of the bottom of the shaft. Is it possible to drain the water from this shaft into the creek with a siphon? Explain how this can be done. *F.—Pa. (B)*

ANS.—A siphon will not lift the water the entire depth of this shaft, since the theoretical lift of a siphon at sea level is only 34 ft., and in practice a siphon will not give good results if the vertical lift much exceeds 24 ft. A pump or a drainage tunnel will be necessary.

QUES. 2143.—From an inner sump, in a mine, the entry rises, 1 in 14 for a distance of 78 feet, and then falls 1 in 21 for a distance of 676 feet; will a siphon work if put in place, under such conditions? If the siphon is 2 inches in diameter, state how much the line will discharge in gallons per hour. *I.—Pa. (B)*

ANS.—The head due to the rise is equal to

$$\frac{78\times 1}{14} = 5.57 \text{ ft.}$$

and the head due to the fall is equal to

$$\frac{676\times 1}{21} = 32.19 \text{ ft.}$$

Therefore the effective head is equal to $32.19-5.57 = 26.62$ ft., and the siphon will work under these conditions if well laid, as the pressure of the atmosphere at sea level will support a column of water about 34 ft. high. The total length of the line of pipe is $676+78 = 754$ ft. Then by the formula

$$Q = .89\sqrt{d^5h} = .89\sqrt{\left(\frac{1}{6}\right)^5\frac{26.62\times 1{,}000}{754}} = \frac{89}{36}\sqrt{\frac{35.305}{6}} = .0598 \text{ cu. ft. per sec.}$$

$$.0598\times 7.48\times 3{,}600 = 1{,}610+ \text{ gal. per hr.}$$

MINE DAMS

QUES. 2144.—A dam in a tunnel supports a vertical head of 80 feet of water; the sectional area of the tunnel is 70 square feet. Find the total pressure on the dam. *F.—Pa. (A)*

ANS.—The weight of 1 cu. ft. of water being 62.5 lb., the total pressure exerted on this dam is

$$\frac{80 \times 62.5 \times 70}{2,000} = 175 \text{ T.}$$

QUES. 2145.—Calculate the thickness of cylindrical wooden dam having a radius of curvature of 30 feet and capable of resisting a maximum water head of 200 feet. *M.—B. C., Canada*

ANS.—The formula for calculating the thickness of a wooden dam is

$$T = .868 \frac{r\,h}{p}$$

in which T = thickness of dam, in feet;
r = shorter radius of dam, in feet;
h = head of water, in feet;
p = allowable compressive strength, per square inch, of material used in building the dam.

then $$T = .868 \times \frac{30 \times 200}{8,000 \times \frac{1}{5}} = 3.25 \text{ ft.}$$

CHAPTER XXIV

COMPRESSED AIR

GENERAL PRINCIPLES

QUES. 2200.—State the use of compressed air as a motive power; explain the principle of an air compressor, and how the power is applied. *M.—B. C., Canada*

ANS.—In mining, compressed air is much used as a motive power in place of steam, for driving engines for haulage, pumping, and ventilating purposes, and to some extent for hoisting, also for undercutting machinery and drills. The principle of an air compressor depends on the fact that when any given volume of air is compressed in a certain ratio, the absolute pressure or tension of the air is increased in the same ratio in which the volume is decreased when the temperature remains the same. The compression of the air, however, causes a rise of temperature in the air compressed, which increases the pressure in a greater ratio than that just given. In practice, this increase of temperature is a detriment, owing to the later cooling and consequent loss of pressure in the transmission of the air to the point where it is to be used. Air compressors are designed, therefore, to maintain the temperature as nearly constant as possible during compression Compression at a constant temperature is called *isothermal compression*, and requires the artificial cooling of the air cylinder so as to absorb the heat of compression from the air; if the heat of compression is allowed to remain in the air during compression the compression is then said to be *adiabatic*. The power is applied to the engine, in the use of compressed air, in the same manner as in the use of steam, steam engines being often operated as air engines with but a slight rearrangement of the valves.

QUES. 2201.—Explain the advantages and disadvantages of the use of compressed air in mining operations.

ANS.—By means of compressed air, power is transmitted with less danger from the surface to the face of the workings where it is used, than by any other method. There is generally less loss in the transmission of power by this means, over long distances with a well-constructed pipe line,

than by either steam or electricity. The danger of the ignition of gas is avoided. Compressed-air motors are simple and easily kept in repair. Another advantage consists in the ventilation of the mine workings and the dilution of the mine gases that issue from the coal and the overlying and underlying strata, by the air discharged from the machines and leaking from the pipe lines. Also, the temperature of the mine air at the face of the workings is reduced by the expansion of the air escaping from the machines.

A disadvantage in the use of compressed air is the cost and time required to install, extend, and repair the pipe-line compressed-air system, as applied to mine haulage. There is always danger of the breaking or dislocation of the pipe line at different points by falls of roof. Again, it is desirable to use the same kind of power in all the operations of the mine, including drilling at the face, haulage, and pumping; but the use of compressed air for haulage requires larger motors, and presents some disadvantage in the necessity of recharging these motors at specified stations in the mine. The use of compressed air in pumping is accompanied to a greater or less extent with the difficulty of keeping the exhaust ports clear, the expanding exhaust air having a tendency to close these ports by freezing the moisture deposited in them.

Ques. 2202.—State the advantages of compressed air over steam in mining operations.

Ans.—The chief advantage consists in the ease with which the power, in the case of compressed air, is transmitted to the working face. The losses due to the condensation of steam and the radiation of heat in a long pipe line are avoided when compressed air is used. In case of a break occurring in the pipe line, there is no danger of scalding men or animals and the air exhausted from the cylinders of the machines, on the roadways or at the working face, is a benefit instead of being a hindrance, as is the case with exhaust steam. In the use of compressed air, the power loss in transmission and compression can be restored, wholly or in part, by reheating the air at or near the face. In mine haulage, compressed-air motors possess the advantage over steam locomotives, in that they require no fire, do not contaminate the air of the mine by gases of combustion or run any risk of igniting the mine gases.

Ques. 2203.—Explain why it is economical in many cases, in mining practice, to employ compressed air or electricity in place of steam power.

Ans.—Because there is less loss in transmitting either of these forms of power over great distances than occurs in a steam line. In mining operations, it is often necessary to use power at many points widely separated, and in such cases there is generally great economy in maintaining a central power plant and transmitting the power to the several points where it is to be used.

QUES. 2204.—Name the two essential points in regard to economy of power in the compression of air.

ANS.—The air should be taken into the cylinder at as low a temperature as possible, and the work of compression should be performed with as little increase of temperature as possible.

QUES. 2205.—Is there any loss by converting steam power into compressed air? If so, what are the causes? *M.—B. C., Canada*

ANS.—Yes; the loss arises from three causes: (1) mechanical losses due to the absorption of power in running the compressor; (2) loss due to the compression of the air under varying conditions relating to temperature, atmospheric pressure, and gauge pressure; and (3) loss due to transmission, frictional loss, leakage, and cooling of compressed air. The total loss of power in compressing air varies from 60 to 80 per cent. of the indicated horsepower of the steam end of the compressor. It varies with the type of machine, the best types of compressors realizing an efficiency of 80 per cent. in the compressor. In compressing air, the irregularity of the load, the greatest load coming at the end of the stroke when the steam-cylinder pressure is a minimum, causes the greatest loss of power.

QUES. 2206.—Explain how the cost of compressing air increases with the altitude above the sea level.

ANS.—Owing to the decrease in the density of the air, there is a less weight of air handled per revolution of the compressor, and as a consequence less power is required to drive the machine, but the reduction in the quantity of air delivered is so much greater than the reduction in the power required to drive the machine, that the result is an increase of power per volume of air delivered. This increase of power under average conditions, amounts to practically 12½ per cent. at 5,000 ft. above sea level, and 20 per cent. at 10,000 ft. above sea level.

QUES. 2207.—Explain the causes of explosions that sometimes occur in the compression cylinder of an air compressor.

ANS.—Explosions are sometimes caused in the air cylinder of a single-stage compressor owing to the heat of compression being sufficient to vaporize the oil used in lubricating the cylinder and to ignite the vapor thus formed. This may arise from an attempt to compress the air to too high a gauge pressure, or from a defect or obstruction in the water-jacket, or from the use of a low-grade cylinder oil for lubricating. Fine coal dust should not be permitted to enter the compression cylinder with air, as this may have a tendency to increase the explosive condition of the air and may even be the sole cause of the trouble.

QUES. 2208.—What is the advantage of compounding when compressing air to high pressures?

Ans.—When air is compressed to say 100 lb. in a single stage or cylinder, a high temperature is produced in the air cylinder, which renders the lubrication of the cylinder difficult, the oil having a tendency to gum and obstruct the ports or valves. Under certain conditions, also, the oil may vaporize and form an explosive mixture of gas and air in the cylinder. In a compound compressor, air is compressed to only about 30 lb. in the first, or low-pressure, cylinder, and the resulting temperature is comparatively low, thereby avoiding the difficulties mentioned. The air discharged from the first cylinder passes through the intercooler, where it is cooled, and enters the second, or high-pressure, cylinder as cold air at a pressure of 25 lb. The second stage of the compression, from 25 to 100 lb., is then accomplished without an excessive rise of temperature. The air compressed in a compound compressor is drier, because much of the moisture of the air is deposited in the intercooler. In air compression, there is a saving of power in cooling the air while compressing. Compounding in the air cylinders produces a better distribution of the load throughout the stroke, and economizes steam by allowing an earlier cut-off in the steam cylinders.

Ques. 2209.—What pressure per square inch will an air-compressing engine produce under the following circumstances: two steam cylinders each 30 inches in diameter, 7-foot stroke, steam pressure 45 pounds per square inch; one air cylinder 36 inches in diameter, and one 20 inches in diameter? *M.—Ill.*

Ans.—From the reading of the question, it may be assumed that this is an air compressor with duplex steam and compound air cylinders arranged as shown in Fig. 1. Assuming a back pressure of 17 lb. above vacuum, the effective steam pressure in each cylinder is 43 lb. per sq. in. Since the

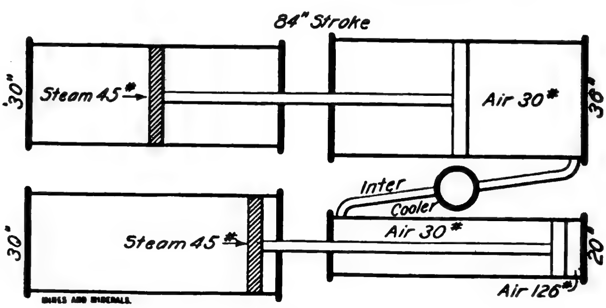

Fig. 1.

total air pressure in the first air cylinder must equal the total steam pressure in the corresponding steam cylinder, the ratio of the steam and air pressure per square inch of area will be equal to the inverse ratio of the areas of the steam and air cylinders, or the square of the inverse ratio of the diameters of these two cylinders; thus, calling the required pressure in the first air cylinder x,

$$\frac{x}{43}=\left(\frac{30}{36}\right)^2=\left(\frac{5}{6}\right)^2,$$

and $$x = 43\times\frac{25}{36} = \text{say 30 lb. per sq. in.}$$

In like manner, for the other side, the steam pressure must be multiplied by the square of the inverse ratio of the diameters of the air and steam cylinders, and calling the required pressure in the second air cylinder x,

$$\frac{x}{43}=\left(\frac{30}{20}\right)^2=\left(\frac{3}{2}\right)^2,$$

and $$x = 43\times\frac{9}{4} = 96 \text{ lb. per sq. in.}$$

But, since the air pressure from the first air cylinder is transmitted through the intercooler with slight diminution due to cooling, to the second air cylinder, and acts to assist the steam pressure to move the piston forwards and compress the air in the cylinder, the final pressure to which the air is compressed in the second cylinder is slightly less than $96+30 = 126$ lb. per sq. in.

Ques. 2210.—What should be the ratio of the diameter of the air cylinder to that of the steam cylinder, in order to compress air to 100 pounds per square inch, when the steam pressure of the boiler plant is 75 pounds per square inch? Assume the efficiency of the compressor as 80 per cent.

Ans.—Approximately, the areas of the steam and air cylinders are inversely proportional to their respective pressures, and the diameters of these cylinders are therefore inversely proportional to the square roots of the pressures. In this case, the ratio of air pressure to steam pressure, assuming an efficiency of 80 per cent., is

$$\frac{100}{.8\times 75}=\frac{5}{3}$$

and the diameter ratio of the air and steam cylinders is therefore $\sqrt{\tfrac{3}{5}} = .77$. That is to say, the diameter of the steam cylinder being 10 in., the diameter of the air cylinder in this case will be $10\times.77 = 7.7$ in.

Ques. 2211.—How is the quantity of compressed air a machine will deliver at any gauge pressure and at any elevation calculated?

Ans.—The free air capacity, or piston displacement, per minute, of the large air cylinder, is divided by the number of atmospheres to which the air is to be compressed; the result will be the quantity of compressed air delivered in cubic feet per minute. The number of atmospheres to which the air is compressed, or the number of expansions in the air delivered, is found by adding the gauge pressure to the atmospheric pressure at that place, and dividing the sum obtained by the atmospheric pressure.

Ques. 2212.—Explain what is meant by the capacity of an air compressor.

ANS.—As used in practice, at the present time, the term *capacity*, or *free air capacity* of a compressor, relates to the piston displacement in the large low-pressure cylinder of the compressor; it does not refer to the amount of compressed air the machine will deliver. In this acceptance of the term the same machine has the same capacity when working under different pressures or at different elevations above sea level, but delivers different quantities of compressed air per unit of power.

QUES. 2213.—Explain what is meant by volumetric efficiency in air compression.

ANS.—*Volumetric efficiency* in air compression is often used to denote the ratio of the volume of air delivered in a compressed state to the piston displacement. The term is used by many writers to denote the ratio of the number of expansions at sea level to the number of expansions at any altitude required to produce the same gauge pressure. This use of the term does not take into consideration clearance and other effects in the cylinder but relates wholly to the effect of elevation above sea level on the work of compression, and is independent of the machine itself.

QUES. 2214.—If the atmospheric pressure at an elevation of 10,000 feet above sea level is 10¼ pounds per square inch, what is the volumetric efficiency for a gauge pressure of 75 pounds neglecting clearances, etc.?

ANS.—The number of expansions in the air at sea level corresponding to this gauge pressure is

$$\frac{14.7+75}{14.7} = 6.10$$

and the number of expansions corresponding to the same gauge pressure at an elevation of 10,000 ft. is

$$\frac{10.25+75}{10.25} = 8.31$$

The volumetric efficiency at this elevation and gauge pressure is, therefore, taking the second definition given in answer to Ques. 2213,

$$\frac{6.1}{8.31}\times 100 = 73.4 \text{ per cent.}$$

QUES. 2215.—What size of pipe should be used to transmit 800 cubic feet of air per minute through a pipe 2,500 feet long, the initial pressure being 100 pounds per square inch and the plant being located 4,000 feet above sea level, where the reading of the barometer is 26 inches under normal conditions?

ANS.—In this case the atmospheric pressure is $26\times.49 = 12.74$ lb. per sq. in., and the number of atmospheres to which the air must be compressed to produce a gauge pressure of 100 lb. is therefore

$$\frac{12.74+100}{12.74} = 8.84$$

The volume of compressed air is then

$$800 \div 8.84 = 90.5 \text{ cu. ft. per min.}$$

Estimating on a velocity of, say 2,000 ft. per min. in the pipe, the area of the pipe is

$$\frac{90.5}{2,000} \times 144 = 6.516 \text{ sq. in.}$$

and the diameter of the pipe is then

$$\sqrt{\frac{6.516}{.7854}} = \text{say } 3 \text{ in.}$$

QUES. 2216.—What size of pipe should be used in transmitting 1,000 cubic feet of air per minute a distance of 4,000 feet, at sea level, when the initial gauge pressure is 60 pounds?

ANS.—The quantity of compressed air under this gauge pressure at sea level is, practically,

$$1,000 \times \frac{15}{15+60} = 200 \text{ cu. ft. per min.}$$

Assuming a velocity of 2,000 ft. per min. in the pipe, the required area of the pipe will be

$$\frac{200}{2,000} \times 144 = 14.4 \text{ sq. in.}$$

The diameter of the pipe is therefore

$$\sqrt{\frac{14.4}{.7854}} = 4.28, \text{ say } 5 \text{ in.}$$

A smaller pipe than this could be used by assuming a higher velocity, but this would require a greater power.

QUES. 2217.—Explain the loss of pressure when compressed air is transmitted to a considerable distance through a pipe line.

ANS.—In the transmission of air through pipes, a portion of the initial pressure is absorbed by the frictional resistance of the pipe. The resistance increases with the rubbing surface of the pipe and the square of the velocity of the air. Since for the same volume of air the velocity is inversely proportional to the area of the pipe, the loss of pressure in transmission is very much increased by the use of pipes of too small a diameter. It is good practice to provide a pipe of sufficient size to pass the required volume of air at a velocity varying from 20 to 50 ft. a sec.; when the velocity exceeds 50 ft. per sec., the loss of pressure in transmission is greater than should be allowed. There is a further loss of pressure whenever there is a fall in the temperature of the air transmitted.

QUES. 2218.—What is the effect of allowing hot compressed air to enter the pipe line for transmission to a distant point?

ANS.—The cooling of the air during transmission to the point where the power is to be used results in a loss of power, which can only be recovered by again heating the air.

QUES. 2219.—A short time ago, a pipe line of a compressing plant was found to be on fire for a distance of several hundred feet into the mine from the bottom of the shaft; the heat was so great that the pipe was red hot in places, and many of the joints of the pipe were melted; what, in your opinion, was the cause of this trouble?

ANS.—The trouble was probably due to the high temperature of the compressed air vaporizing the oil used in the lubrication of the cylinder and igniting the vapor so formed. The ignition may have started in the compression cylinder where the temperature would naturally be higher, or it may have started in the pipe at a point where the mixture of vaporized oil and air was particularly inflammable. The tendency of the oily vapor to ignite may have been increased by the presence of some fine coal dust floating in the air and drawn into the compression cylinder.

TYPES OF AIR COMPRESSORS

QUES. 2220.—Describe briefly, and in a general way, the several types of air compressors.

ANS.—The several types of air compressors are described by the general terms *straight line*, *duplex*, and *compound*. There are numerous forms and combinations of these three general types. A compressor in which all the steam and air cylinders are arranged in the same straight line, or tandem, is called a straight-line compressor. A duplex compressor consists of two straight-line compressors arranged side by side and connected by a single shaft carrying a flywheel; the cranks of these two engines are set at right angles to each other. A *half-duplex compressor*, as the term indicates, is one half of a duplex machine so arranged that the other half can be added at any time when required. A *compound compressor* is one in which the air is compressed in two or more stages; high-duty compressors are sometimes built to compress air in four stages or cylinders. Compound air compressors may be arranged with simple duplex steam cylinders, or compound steam cylinders may be used on each side or cross-compound cylinders may be used. When the air cylinders of a compound compressor are arranged tandem, it is a straight-line compound compressor, but at times the air cylinders are arranged as a *cross-compound* by placing the high-pressure air cylinder on one side, and the low-pressure cylinder on the other. Air compressors are driven by steam, electricity, water-power, gas engine, belt, rope drives, chain, or gears.

QUES. 2221.—What classes of compressors are best adapted to haulage? Give reasons.

ANS.—In haulage, the required pressures are necessarily high, ranging from 500 to 1,000 lb. gauge pressure. For this work, compound compressors are better adapted, because when air is compressed in two, three, or four stages, a high pressure can be attained with a comparatively small range of temperature in the compression cylinder, and the result is a greater saving of power.

QUES. 2222.—In what respect does a duplex steam air compressor possess an important advantage over a single straight-line compressor?

ANS.—The duplex steam end permits a more even distribution of the load, the crank-arms being set at right angles to each other. Also, since one steam cylinder assists the other, an earlier cut-off may be adopted in the same cylinders, resulting in a greater economy of steam. In case one side is disabled, the compressor can still be run on half duty as a straight-line compressor, supplying at least a portion of the air required.

QUES. 2223.—What is meant by a mountain or high-altitude compressor, and in what respect does such a compressor differ from other compressors?

ANS.—A *mountain*, or *high-altitude, compressor* is one that is designed to compress the lighter air of a higher altitude to the same gauge pressure as another machine produces when working at sea level. At any altitude above sea level, a greater number of compressions is required to produce the same gauge pressure. This requires an earlier cut-off, which would decrease the capacity of the machine if the air cylinder were not made proportionately larger. Hence, the large, or low-pressure, air cylinder of a mountain compressor is made larger than the same cylinder of a compressor designed to work at sea level and the valves are arranged to give an earlier cut-off.

QUES. 2224.—Explain the purpose of a flywheel in an air compressor.

ANS.—The flywheel promotes the even distribution of the load and reduces the severity of the strains, by making the motion more uniform throughout the stroke. In a single straight-line compressor, the flywheel also carries the engine over the dead center.

QUES. 2225.—What is the usual pressure employed for operating drills, coal cutters, and pumps? What cylinder pressure is employed in compressed-air locomotives, and what tank pressure is required? What pressure is commonly required in the pipe line for charging compressed-air locomotives?

Ans.—Drilling and cutting machines and pumps are generally operated under pressure ranging from 60 to 100 lb. per sq. in.

Haulage motors are designed for higher pressure up to 150 lb. per sq. in. at the throttle, the tank pressure varying from 600 to 800 lb.

A pipe-line pressure varying from 600 to 1,000 lb. per sq. in. is commonly used in mine haulage.

Ques. 2226.—Since a higher pressure is required in the pipe line for haulage purposes than for operating mining machines, pumps, etc., is it economical to use the air compressed for haulage purposes in the operation of mining machines? State the reason why.

Ans.—It is possible to reduce the pressure required for haulage to that required for operating mining machines by allowing the air to escape from a pipe line carrying a gauge pressure of 600 to 1,000 lb. into another, but this reduction of pressure will result in a loss of power, since the expansion of any air, steam, or gas is always accompanied with a loss of power. For this reason, it is not economical to use high-pressure air for the operation of machines requiring a lower pressure.

Ques 2227.—Using air at 60 pounds gauge pressure, if there is required 1,100 cubic feet of free air per minute for the operation of twenty-five 2-inch drills at sea level, what quantity of free air would be required for the same work at an elevation of 5,000 feet above the sea level where the barometer reads 25 inches?

Ans.—The atmospheric pressure corresponding to this barometer is $25 \times .49 = 12.25$ lb. per sq. in. At sea level, a gauge pressure of 60 lb. corresponds to

$$\frac{14.7+60}{14.7} = 5.08 \text{ expansions}$$

while the number of expansions for the same gauge pressure at an elevation of 5,000 ft. is

$$\frac{12.25+60}{12.25} = 5.90$$

The volumetric efficiency at this elevation and gauge pressure is therefore

$$\frac{5.08}{5.90} \times 100 = 86+ \text{ per cent.}$$

The required quantity of free air at this elevation would therefore be

$$1{,}100 \div .86 = 1{,}279, \text{ say } 1{,}300 \text{ cu. ft. per min.}$$

CHAPTER XXV

ELECTRICITY

APPLICATIONS IN MINING

QUES. 2300.—To what use is electricity applied in the operation of a coal mine? Name the four electrical units in common use. *M.—B. C., Canada*

ANS.—Electricity is applied in coal mining to the purposes of haulage, hoisting, pumping, lighting, and signaling, and for operating drills, coal-cutting machines, ventilating fans, and other machinery used in and about mines. The four electrical units in common use are the ampere, volt, ohm, and watt.

QUES. 2301.—Define the following electrical units: the ampere, volt, ohm, and watt. *M.—B. C., Canada*

ANS.—The four electrical units in common use are as follows: the ampere, volt, ohm, and watt. The *ampere* is the unit of strength or the intensity of the electrical current, and expresses the volume of the current. It corresponds to the expression of the flow of water through a pipe or the volume of air passing in an airway.

The *volt* is the unit of electromotive force, and corresponds to the head of water producing a given flow in hydraulics, or the pressure producing a given circulation of air in ventilation.

The *ohm* is the unit of resistance, and expresses the amount of resistance encountered by a current of 1 ampere under a pressure of 1 volt.

The *watt* is the unit of power, and expresses the power required to pass a current of 1 ampere under a pressure of 1 volt.

ADVANTAGES AND DISADVANTAGES OF ELECTRIC POWER

QUES. 2302.—What are the advantages and disadvantages of using electricity for power or other purposes? *I.—Pa. (A)*

ANS.—The advantages of electricity as applied to mining are the following: the cost of generation is low; the current is easily conducted to any

point of the mine workings; conducting wire is cheap, in comparison with the requirements of other systems; the system is pliable and well adapted to the changing conditions in mine workings; the loss of power in transmission is small; electrical apparatus is readily installed; the system not only furnishes power for motor haulage, but also light and power in the mine workings, and a means of signaling.

The troublesome features in regard to the application of electricity to mining operations are the following: incandescence of the conducting wires; sparking occurring in the motor or caused by a broken circuit; the producing of a voltaic arc between two carbon terminals; the danger to men and animals from contact with live wires.

GENERATION AND TRANSMISSION OF ELECTRIC POWER

QUES. 2303.—How is the electric current generated before it is transmitted? How is the transmitted electric power utilized? *I.—Ia.*

ANS.—The electric current is generated by a machine called a dynamo or generator, which is driven by steam or water-power. A dynamo consists of a number of electromagnets and conductors so arranged that in the operation of the machine the conductors are revolved in the magnetic field produced by the magnets, by which means an electric current is set up in the conductors.

Electric power is utilized by means of an electric motor, which is a machine consisting of a number of conductors so arranged that they are free to revolve in a magnetic field when the transmitted current passes through them. The current passing through the conductors reacts on the magnetic field, causing the conductors to revolve, thus converting the electrical energy into mechanical energy. The operation of a motor is exactly the reverse of that of a generator.

QUES. 2304.—How is electrical energy transmitted into mines? What three things should be carefully proportioned for the safe transmission of electrical energy? *I.—Ia.*

ANS.—Electrical energy is conducted into the mine by a copper wire, either bare or insulated. The third-rail system of electric haulage is not generally adopted for mine haulage, owing to the greater danger, in this system, of fatal accidents due to men and animals coming in contact with the live rail.

The three elements to be considered in the transmission of electrical energy are: the electromotive force (E. M. F.), the volume or strength of the current, and the resistance, or load, represented by the three electrical units, volt, ampere, and ohm. The three practical considerations in the transmission of electrical power are: (1) the cost of power as compared with that of copper; (2) the length of the line; (3) the size and number

of motors employed. The size of the wire conducting the current into the mine should be such as to accommodate a sufficient current to move the required load under a safe voltage. The high price of copper, however, necessitates the use of as small a wire as practicable, and tends to increase the necessary voltage, the size of wire and amount of copper varying inversely as the square of the voltage employed. Doubling the voltage necessitates but one-fourth the outlay for copper. A current of 250 volts is usually preferred for mine work, although 500 volts is often employed. Having adopted a certain voltage, the strength of the current and size of wire required is determined by the length of the transmission and the number and size of motors employed; in other words, the load to be moved and the resistance of the line.

Ques. 2305.—What advantage is gained by the use of electric centrifugal pumps in mining coal? *F_1.—Ala.*

Ans.—Until recently, the use of centrifugal pumps has been confined to small lifts, and they have found no general application in mining. Recently, however, a multiple centrifugal pump has been designed for high lifts. It is stated that this pump will lift water from a depth exceeding 2,000 ft. The advantage of the electric centrifugal pump is the direct application of the power to the pump shaft; the pump itself is claimed to be exceedingly efficient. The use of electric powe. for pumping avoids the inconvenience of exhaust steam in the shaft an mine workings. The power is more easily transmitted to the point where it is to be used, and there is less loss in the transmission. It is generally a great advantage to use the same kind of power throughout the mine, for running the machines at the face and for haulage and pumping.

VOLTAGE FOR MINE USE

Ques. 2306.—What voltage do you prefer for use about a mine? *F.—Pa. (B)*

Ans.—The voltage for mine haulage varies from 200 to 500 volts, 250 volts being often preferred. Better insulation is possible and less sparking results with a low than with a high voltage, and a less loss also results in the transmission of the current. A high voltage, however, reduces the cost of wire necessary for the distribution of the current over a large area of the workings. A current of 500 volts may not kill a man who is physically strong, but will kill a mule.

Ques. 2307.—What is a safe voltage to use with an electric haulage, and if you are carrying 500 volts, what is necessary to do to retain the same power and reduce the voltage to 250 volts? *F_1.—Ala.*

ANS.—In mining practice, it is safer to use a current of 250 volts than one of 500 volts, owing to the danger of mules and men coming in contact with the wires in the narrow space of the mine openings. While a current of 500 volts will not ordinarily kill a man in sound condition, such a current is sufficient to kill a mule, and for this reason can hardly be called a safe current for mine work. For the same power, the amount of copper varies inversely as the square of the voltage; hence, to reduce the voltage to one-half will require four times the sectional area in the conducting wire, or a wire having twice the diameter.

DANGERS FROM USE OF ELECTRIC POWER

QUES. 2308.—What dangers arise from the use of electricity in mines, and what methods would you employ to prevent accidents therefrom? *F.—Pa. (B)*

ANS.—Among the dangers arising from the use of electricity in mines may be mentioned: incandescence of the conducting wires; sparking occurring in the motor or caused by a broken circuit: the producing of a voltaic arc between two carbon terminals. Any of these occurrences would be dangerous in a gaseous mine. There is also the danger of men and mules coming in contact with a live wire and receiving a shock of greater or less severity. To avoid these dangers as far as possible, an alternating current should be used in preference to a continuous current. Large size motors are safer than the smaller types, because any variation in the load affects them less. Carbon brushes should be used in preference to copper, because they have less tendency to spark. Lead or tin safety fuses should not be employed, but fusing wires protected by a shunt should be substituted in their place. The conducting wires should be securely fastened to the roof in such a position that a person or mule will not be liable to come in contact with them while walking in the entry. Strict regulations should be made and enforced in relation to the handling of any of the switches or wires by persons not authorized to use them; and as far as possible, the traveling of men and mules should be prohibited on entries where electric wires are hung. Danger signals should be displayed at the mouth of the mine and wherever men or animals are liable to come in contact with electric conductors.

QUES. 2309.—State the conditions under which you would recommend the use of electricity for power in mines. *F.—Pa. (B)*

ANS.—The use of electric power in mines is particularly adapted to long and tortuous or winding haulage systems, and where district haulage is necessary or where the motor is taken into the rooms either electricity or air should be used in preference to rope haulage. The use of electricity is not advisable in a gaseous mine.

QUES. 2310.—What precaution would you suggest to guard the employes in a mine from possible accidents due to the use of electricity? *I.—Pa. (A)*

ANS.—The wire used to conduct the electric current into the mine should be properly secured to the mine timbers near the top and to one side of the road, so as to be out of the way of men and animals. As far as practicable, all conducting wires should be kept off from traveling ways and where such traveling ways cross the haulage roads the conducting wires should be insulated or protected in such a manner as to render the possibility of accident from contact with the wires extremely remote. Proper danger signs should be placed in a conspicuous position at all points where the conducting wire is of necessity exposed and men and animals must pass. Electric power should not be used in a gaseous mine. Where coal-cutting machines or drills are driven by electricity at the face of the workings, due precautions should be taken to avoid the danger of men or animals coming in contact with a live wire.

QUES. 2311.—What practical methods would you adopt and enforce in and about mines to reduce the liability of accidents from the use of electricity? *F.—Pa. (B)*

ANS.—All employes should be informed in regard to the dangers of electricity, and notices in the different languages spoken about the mine should be posted at the mouth of the mine and other conspicuous places, warning persons of the danger of touching the wires or anything in contact with the wires conducting electric power into the mine. These wires should be well secured to the mine timbers; and as far as practicable they should be kept off the traveling ways, and protected at all points where men or animals are liable to come in contact with them. No one should be permitted to operate electric machinery, who has not been thoroughly instructed in the operation of the machine he is to handle.

QUES. 2312.—Do you consider electricity as a motive or lighting power dangerous in mines producing explosive gases? *I.—Pa. (A)*

ANS.—In the use of electricity in gaseous mines, there is always the danger of the ignition of gas by the sparking that may occur from the brushes of the motor, the trolley, or the wheels on dirty rails; the breaking of the wire conducting the current; the short-circuiting of the current; or the breaking of incandescent lamps. For this reason, the use of electricity for the purposes of power or lighting in gaseous mines should be considered dangerous.

QUES. 2313.—How many deaths were due to electricity as used in and about the mines of Pennsylvania during the years 1901 and 1902? *I.—Pa. (A)*

Ans.—Reports of the Bureau of Mines of Pennsylvania state that seven deaths occurred in 1901 and seven in 1902 in the bituminous mines of Pennsylvania, due to shocks from electricity. The number of deaths occurring from this cause alone in the anthracite region is not given.

CHAPTER XXVI

DUTIES OF MINE OFFICIALS*

QUES. 2500.—What are the duties of superintendents, mine foremen, fire-bosses, and all other workmen employed in bituminous mines of this state? *I.—Pa. (B)*

ANS.—*Superintendent.*—The duties of the superintendent of a mine are to provide and maintain the necessary machinery and supplies required for the operation of the mine in accordance with the mine law, and to place at the disposal of the mine foreman the necessary means for operating the mine in compliance with the law; also to make, or cause to be made, an accurate map or plan showing the land lines, mine workings, openings, directions of air-currents, elevations and bearings of tunnels, slopes, and entries, together with the elevations of the working face at the boundary line, and to extend such map at least once in 6 mo., and to furnish a copy of the same to the mine inspector of the district in which the mine is located; also to furnish the mine inspector of the district, on or before the 25th day of January of each year, a report showing the name of the operator and officers of the mine, and the quantity of coal mined during the year, and such other information as may be from time to time required by the inspector.

Mine Foreman.—The duties of the mine foreman are to keep a careful watch over the ventilating apparatus, and the airways, traveling ways, pumps, and drainage of the mine, and to instruct the miners in regard to the timbering of their places, and as far as possible to see that such instructions are obeyed. He must see that all dangerous coal, slate, and rock are taken down or carefully secured, on all haulage ways, airways, and traveling ways; he must see that a sufficient quantity of props, caps, and other timbers of suitable size are sent into the mine and delivered to the men in their working places as required. The mine foreman shall measure the air-current at least once a week, at the inlet, outlet, and at or near the face of each entry, and keep a record of such measurements. The mine foreman

*The replies given in this chapter are intended merely to show the method of answering questions that relate to legal requirements. The answers to similar questions should be taken from the latest mine law in each state. The answers to questions similar to those given in this chapter may also be greatly modified by the local conditions. For instance the method in which a mine inspector should apportion his time or a foreman should perform his duties cannot be answered except in a very general way as these must be determined by the local conditions.

is responsible for the proper and thorough construction of all doors, stoppings, brattices, overcasts, or other mine work pertaining to the ventilation of the mine, haulage and hoisting of the coal, and the safety of the men employed.

Fire-Boss.—The fire-boss is entrusted with the examination of the mine for gas; he must enter the mine each morning, within 3 hours previous to the men commencing work, and, proceeding with the air, must examine the airways and each working place for gas, using for this purpose a safety lamp, and leaving a suitable mark at the face of each working place examined, as evidence of such examination. He must not allow any person, except those duly authorized, to enter or remain in any portion of the mine containing a dangerous accumulation of gas. He shall frequently examine the gobs and abandoned places, and all falls of roof or coal, to ascertain if gas is being given off; he shall fence off, and place danger signals at the entrance of all places where gas is found in dangerous quantity. He shall report the results of his examination to the mine foreman, and also enter the same in a book kept for that purpose at the mine, signing his name to each report.

Miner.—It is the duty of each miner to examine his place before commencing to dig or load coal; also to ascertain what, if any, marks have been left by the fire-boss indicating the examination of the working place. It is his duty, as far as possible, to keep his working place timbered and in a safe condition during working hours. If this is not possible, he shall at once cease working and inform the mine foreman or his assistant of the danger, placing a plain warning at the entrance to the place before leaving the same, in order to prevent others from running into the danger. It is his duty to mine and properly sprag the coal, and to exercise great care in examining the roof and coal before beginning work.

Drivers shall see that brakes or sprags are properly adjusted to all cars before descending steep grades, and shall leave cars or trips where they will not obstruct the ventilating current and endanger other drivers. *Trip riders* or *runners* shall see that all hitchings are safe, and the cars of a trip properly coupled before the same is started, and if any defect is discovered in the rope, link, or chain, he shall hold the trip until the trouble is remedied. *Furnace men* must tend the mine furnace regularly, and notify the mine foreman whenever likely to be absent; they must keep a clear, brisk fire, allowing no accumulation of ashes on the bars or in the ash-pit, and cool the ashes before removing them; they must promptly obey the instructions of the mine foreman.

These are the legal requirements, but in addition to these, it is the duty of every one about a mine from the owner to the youngest trapper boy to observe every requirement of the mine law, stated or implied, and to use the utmost possible care to prevent personal injury or injury to fellow workmen. No unnecessary risk should be taken and undue care should be the rule rather than carelessness and each employe or official should assist in enforcing the strict discipline that is absolutely necessary about a mine to minimize the number of accidents.

INSPECTOR

QUES. 2501.—What are the duties of a mine inspector?

I.—Pa. (*B*)

ANS.—The mine inspector is required by law to give bond for the faithful discharge of the duties of his office; to open and maintain an office in his district; to devote all his time to the duties of the office in the examination of the mines of his district, investigating fatal mine accidents, attending inquests, collecting and giving testimony relating thereto, making reports, examining mine maps, etc. The Bituminous Mine Law requires the mine inspector to examine each mine at least once every 3 months. The mine inspector must assure himself that the provisions of the mine law are being carried out in each mine of his district, and must make a record of each examination made. He must fill out a blank form of report and post the same in the office of said mine, such report to give the date of the visit, the number of cubic feet of air in circulation, and where measured. He must furnish each mine with a suitable record book for the use of the fire-boss and mine foreman in making their daily reports of the condition of the mine. He must institute proceedings in the Court of Quarter Sessions of the county against any person or persons violating the mine law. It is the duty of the mine inspector to consult with two other mine inspectors in regard to the unsafe condition of any mine, and with them to notify the superintendent of the mine to remove such condition or close the mine, and if necessary to apply in the name of the Commonwealth to the Court of Common Pleas of the county, or to the Judge of said Court in Chambers, for an injunction against said mine. When notified of a mine accident, he shall go at once to the place and assist all in his power in the work of rescue, investigate the cause of the accident, and make a full record thereof, and secure the proper persons as witnesses. He must be present at any inquest held by the coroner upon the death of any person or persons resulting from such accident, and must furnish such testimony as will thoroughly inform said coroner of the cause of death.

QUES. 2502.—How should an inspector of mines divide his time in order to properly perform each of his several duties?

I.—Pa. (*A*)

ANS.—He should divide his time into periods for the performance of the following duties: Inspection of the several mines in his district as regularly and frequently as the number of mines and the time required for his other duties will permit. Attention to correspondence addressed to his office. Making written reports to the Chief of the Department of Mines, and when necessary drawing the attention of operators, superintendents, and mine foremen to the requirements of the law. Special investigation where loss of life has occurred, or where the lives of miners are in danger, at any mine in his district. Notice to the coroner to hold an inquest to inquire into the death by accident of any person or persons killed at a mine.

Personal attendance on the inquest. Finally, he must so apportion his time that some of his duties can at any time be deferred for the performance of others that demand immediate and prompt attention, either in his own or another district, upon the call of a fellow inspector.

QUES. 2503.—If appointed state mine inspector, how would you proceed to make your first examination of a mine? *I.—Ia.*

ANS.—I would proceed to the mine, make myself acquainted with the mine officials, and after a brief inspection of the mine maps in the office, I would proceed at once to examine, minutely and in detail, the equipment at the surface. I would begin at the engine room, examine the engine, take notice of its style and manner of working, and particularly of the brake controlling the motion of the drum. I would converse briefly with the engineer in charge, and would then proceed to examine the boilers and fittings. I would next proceed to the shaft and examine carefully the hoisting ropes, cages, wings, safety catches, gates, and other appliances. Before going into the mine, I would examine carefully the ventilating apparatus, if this were at the surface, making note in my memorandum book of the speed of the fan, its size, and whether the same was an exhaust or a blow-down fan. I would have the engineer lower me slowly down the shaft, giving me an opportunity to examine the shaft lining as I descended; I would observe carefully the working of the cage in the shaft, the signals given at the upper and lower landings, as well as the signals given in response by the engineer. I would examine carefully the bottom of the shaft, its timbering, the arrangement of tracks, and the manner of handling the cars. I would notice if there was provided a proper manway around the shaft, and would next proceed to the intake airway or the foot of the downcast shaft. Having carefully observed here if the speed of the fan, as ascertained by counting its pulsations, was the same as it was when I was at the surface, I would select a suitable place in the airway, not far from the foot of the downcast, and having measured the size of the airway at this point, I would as carefully as possible obtain an average reading of the anemometer at that point of the airway; and would make a memorandum of the same in a book carried for the purpose, being careful to note also the date of my visit. I would then proceed inby upon the intake airway, observing the character of the stoppings, timbering, and the general condition of the air-course. I would examine also every door, overcast, or brattice upon my way, as I followed the air on its course through the mine. I would, from time to time, measure the air at different points in the airway, and ascertain if the full amount of air was passing. This would show whether the doors, stoppings, bridges, etc. were air-tight, or if the air was leaking at any point. I would measure the quantity of air going into each split at the mouth of the split. I would measure the air, also, at the inside break-through of each split, and would see that these break-throughs were all of a proper size, and were free from any incumbrances, such as tool boxes, powder kegs, etc. I would go to the face of the rooms and examine carefully the condition of the working face; the amount of timber and

caps on hand in the several rooms and working places. I would talk with the men, giving them a fair opportunity for making any suggestions whereby, in their opinion, the general conduct of the mine might be improved. I would further examine all airways and haulage roads with respect to their size, timbering, drainage, and general arrangements. Returning to the bottom of the shaft, I would examine carefully the pumps, and inform myself particularly in regard to the efficiency of the drainage system of the entire mine.

QUES. 2504.—Name three instruments necessary for you to perform the duties of mine inspector. When, where, and how are they used? *I.—Pa. (B)*

ANS.—The mine inspector is supposed to use the anemometer and the water gauge in determining the quantity of air in circulation in the mine, and if necessary the power effective upon the air.

The anemometer is used in taking observations in the main intake airway at the foot of the downcast, as well as for observing the quantity of air passing into the several splits of the mine, and the quantity in circulation at the face or passing through the inside break-throughs near the face. The water gauge is only employed in making special tests in the fan drift or at the bottom of the downcast shaft. Another instrument of importance to the mine inspector is the barometer, the reading of which should be observed both before and after making observations in a mine. The barometer is usually read at the surface.

QUES. 2505.—If you were appointed a mine inspector, would you devote the whole of your time to your office? *I.—Pa. (B)*

ANS.—Art. X, Sec. 11, of the Bituminous Mine Law of Pennsylvania requires that each inspector of bituminous coal mines shall devote the whole of his time to the duties of his office; and the question therefore requires an answer in the affirmative.

QUES. 2506.—If the mine inspector found a mine in such condition as to jeopardize life and health, what should be his mode of procedure? *I.—Pa. (A)*

ANS.—In this case, he should give orders that the men be at once withdrawn from the mine, and not permitted to return until the mine be placed in a safe condition. If the owner, operator, or agent of the mine refuses to withdraw the men upon the order of the inspector, it becomes the duty of the inspector, acting in behalf of the Commonwealth, to apply to any court of law or equity having jurisdiction in the district in which the mine is located, for an injunction prohibiting the working of said mine until the same has been placed in a safe condition. The inspector must give written notice to the owner, operator, or agent of the mine not less than 24 hours previous to making the application in court.

Ques. 2507.—What does Article XV, Section 1, of the mine law cover? *I.—Pa. (A)*

Ans.—Art. XV, Sec. 1, of the Anthracite Mine Law of Pennsylvania provides for an injunction prohibiting the working of a mine, to be issued by any court of law or equity having jurisdiction in the district in which the mine is situated. Upon the application of the inspector of mines, after having given 24 hours' written notice of his intention to apply for such injunction to the owner, operator, or superintendent of the mine, an injunction shall be granted by said court prohibiting the further working of such mine or colliery in contravention of the provisions of the mining law.

DUTIES OF FOREMEN

Ques. 2508.—Describe in detail the duties of a mine foreman as prescribed in the mine law. *F.—Pa. (B)*

Ans.—Art. VI of the Bituminous Mine Law of Pennsylvania prescribes that the mine foreman shall devote all his time to his several duties at the mine when the latter is in operation, or in case of necessary absence shall authorize an assistant to act for him. He shall keep a careful watch over the ventilating apparatus, and the airways, traveling ways, pump, pump timbers, and drainage in the mine. He shall oversee the work of the miners, as far as it relates to the security of their working places; he shall see that all dangerous coal and slate and rock are taken down or made secure in the rooms and traveling ways and haulage ways, and shall provide a sufficient quantity of props, caps, and timbers of suitable size, and shall deliver the same in the working places of the mine when notified by the workmen that these are required. He shall attend to making the proper cut-throughs in all room pillars and entry pillars, and shall see that the ventilating current is properly conducted through these by means of canvas or other doors placed at suitable points in the entries. He shall measure the air-current at least once a week at the inlet and outlet, and at or near the faces of the entries in the mine, and shall keep a record of such measurements. He shall require the workmen to use locked safety lamps only, when and where required by law. He shall give prompt attention to any places reported to him as dangerous by any person working in the mine, and shall visit and examine every working place in the mine at least once every alternate day when the mine is at work. He shall each day countersign the report entered by the fire-boss in the book kept at the mine for that purpose, and shall himself each day enter and sign, in a book provided by the mine inspector, a report of the condition of the mine, clearly stating any danger that has come under his observation during the day, and also whether he has a proper supply of material on hand for the safe working of the mine, and whether all the requirements of the law are being strictly complied with. He shall once each week enter in said book, in ink, a true record of

all air measurements required by law. In case no superintendent is employed at the mine of which he has charge, the mine foreman shall perform the duties required by law of the superintendent, maintaining a full supply of all materials and supplies required to preserve the life and safety of the employes, or withdrawing the men from the mine or part of the mine affected until such supplies of material are received. He shall see that all stoppings in airways are properly built, and that the entries at such places where it is necessary to apply or remove sprags or brakes from mine cars shall have a clear level width of not less than $2\frac{1}{2}$ ft. between the side of the car and the rib of the entry. He shall direct that all miners undermine the coal properly before blasting it, and that blasting shall be done only at such hours as he shall direct. He shall order the miners to set sprags under the coal when necessary for safety while undercutting, the sprags to be set at distances not exceeding 7 ft. apart. He shall not allow improper drawing of pillars. He or his assistant shall superintend the relighting of the furnace in mines generating firedamp. In case of accident to the ventilating machinery, he shall immediately order the men to withdraw from the mine and not to return to their work until the ventilation has been restored in the mine. He shall see that all dangerous places are properly fenced off, and danger signal boards hung in a conspicuous position upon such fencing. He shall visit all the accessible portions of old workings as often as is necessary to assure himself of their safe condition. He shall provide a book or sheet in some convenient place, upon which each miner can designate his number, the quantity of props required, their approximate length, and the number of caps and timbers needed. The sheet for each day shall be dated and preserved 30 da. from that date. He shall see that any person engaged in the mines is given medical or surgical treatment, if the same is needed. He shall report monthly to the mine inspector of the district, upon a blank furnished by the inspector for that purpose, all accidents resulting in personal injury.

NOTE.—This question is often asked as follows: "What particular points should receive the attention of the mine boss when making his daily rounds of the mine?" "What are the duties of a mine foreman?"

QUES. 2509.—What duties, other than those set out in the law, are mine bosses usually required to perform at the mines of Indiana? *F.—Ind.*

ANS.—To employ and discharge workmen; to keep the time of the day men; to lay off and direct the underground workings of the mine; to make measurements of narrow work and report the same to the bookkeeper; to make allowances for dead and deficient work; to direct the employment of day men in and about the mine; to take all possible steps to produce coal with the greatest economy consistent with the safety and comfort of the employes of the mine.

QUES. 2510.—What qualifications are necessary to make a successful mine foreman other than that required by law? *F.—Pa. (B)*

Ans.—A mine foreman should have a thorough knowledge of all mining operations and methods, and of the different types of mine machinery, and should know the application and adaptation of each class of machinery to different conditions. He should understand and be able to judge of what a good day's work consists in or about the mine; he should be a good judge of human nature, and be able to handle men skilfully and successfully; he should have firmness, self-control, and perseverance, and should be a man devoid of biased opinions either with regard to men, machinery, or methods of working. He should be fearless, prompt, patient, cautious, prudent, industrious, observing, and always ready to adopt improved means or methods of performing the work.

Ques. 2511.—What should be the first points to be looked after by a mine boss on entering a mine in the morning?

F.—Ind.

Ans.—Assuming that the mine boss has acquainted himself with the report of the fire-boss, and has a full knowledge of the condition of the working places of the mine, his first duties on entering the mine are to assign the company men or shift hands to their several duties, at different points in the mine. If everything is in proper working order at the bottom and the pumps or ventilating apparatus do not require special attention, he proceeds at once to the inside workings, having given orders that the bottom shall be cleared of any coal or dirt brought out by the night shift. He proceeds to first look after the work of the drivers, and arrange for the proper movement of the coal to make up the trips. When everything is moving satisfactorily and the coal coming regularly to the inside parting where the trips are made up, the boss is free to proceed to the working face. He should visit the rooms regularly, and see that each room has its proper supply of timber and air, he should also assure himself that the timber furnished to the rooms is being properly used, and should caution the men in regard to any top that he considers dangerous, acquainting them always, as far as possible, with regard to faults and slips they are liable to meet.

Ques. 2512.—On entering upon your duties as mine foreman of a colliery that has been in operation some time, what would you consider to be your duty in order to make a reputation for yourself and do justice to your employer? What stand would you take with your men and what would be your first duty upon taking charge? *F.—Pa. (B)*

Ans.—It should be the aim and purpose of a man to reduce the running expenses of the work in his charge, and to increase the quantity and quality of the output as far as practicable. It should be his endeavor to produce the largest output at a minimum cost; to treat all the men in a fair and unbiased manner, and have them understand that he expects a day's work for a day's pay. He should also try to improve the general feeling among the men in charge of the different departments and to bring them into

harmony of action; to systematize the work wherever there appears to be loss of time or labor, and to exact economy of material and labor.

The first duty upon taking charge would be to thoroughly acquaint himself with the details of the work and the abilities and capacities of the several men for performing their special work, to investigate the amount of work done by each man; to improve the methods of operating, with a view to reducing the expense per ton of output, using tact in making changes and not unnecessarily antagonizing established customs. He should also try to improve the machinery in use, with respect to the efficiency of each machine.

QUES. 2513.—What is the object to be attained by requiring the mine foreman to visit the working places every alternate day when the men are at work? *F.—Pa. (A)*

ANS.—The object is to secure a regular and systematic inspection of all the working places in the mine. In a large mine, it would not be possible for the mine foreman to visit every working place in 1 day and do justice to his work of inspection. If the mine is so large that a regular visit cannot be made every alternate day, it should be divided into inspection districts and supervised by two foremen. By the operation of this law, the mine foreman is compelled to acquaint himself at least every alternate day with the condition of every working place under his supervision, and he is thus justly held responsible for the safe condition of all the working places in his charge, which is the object the law contemplates.

QUES. 2514.—Name the cases in which the foreman should consult the mine maps. *F.—Pa. (A)*

ANS.—It would be difficult to name any pertinent cases in which the mine foreman should not consult the maps of the mine. He should consult these especially when working near land lines and before ordering any important work, such as the driving of entries or headings toward abandoned workings, the drawing of entry or room pillars, or the construction of a mine dam for the purpose of holding back an accumulation of water. The mine maps should be consulted very carefully before making any alteration in the system of ventilating the workings. They should be consulted carefully with respect to any work undertaken for the purpose of arresting the progress of a squeeze. The work of rescue following any serious mine accident always requires a careful inspection of the mine maps.

QUES. 2515.—What are the duties of the mine manager in reference to the machinery employed about a mine; and what steps would you consider it necessary to take in the fulfilment of such duties? *M.—Ill.*

ANS.—The mine manager must appoint a competent person whose duty will be to inspect and report to him the condition of all machinery, in reference to its efficiency and safety. He must satisfy himself that all the

apparatus for hauling, hoisting, pumping, ventilating, raising steam, and transmitting power is in a state of efficiency and that the same is properly protected at all points according to the requirements of the mine law, and in such a manner as to secure a reasonable amount of safety to all persons employed in or about the mine.

QUES. 2516.—If you were acting as mine foreman, at a gaseous mine, what instructions would you give to your fire-bosses relative to the performance of their duties? *B.—Pa. (B)*

ANS.—The mine foreman is at all times responsible, by law, for the proper performance of the duties pertaining to the fire-boss. He should therefore always satisfy himself that these men under his charge are fulfilling their duties as required by the mine law; and further, that they are men in whom he can place confidence. He should examine their reports daily; and if, at any time, he is in doubt in regard to the same, he should make a personal examination of the places. The mine foreman should inform his fire-bosses that he will hold them personally responsible for the conditions existing in their respective districts; and that he expects them to spare no pains or effort to make the entire mine safe; and further, that they shall run no risk, but report to him, at once, any places in regard to which there may be a doubt.

QUES. 2517.—What instructions would you give your miners relative to their duties when hiring them; also when on your daily rounds? *F.—Pa. (B)*

ANS.—On hiring the miners I would question them upon the provisions of the General Rules of the act relating to the bituminous coal mines of Pennsylvania and draw their attention to the penalties they are liable to, and the dangers they expose themselves and others to, when they do not put in practice the provisions of these rules. On my daily rounds, I would instruct them to secure themselves with timber when required and urge upon them the necessity for promptly reporting the presence of danger to themselves or to the mine.

QUES. 2518.—What duties imposed by law on the owner, operator, agent, or lessee are usually performed by the mine boss? (Give the principal heads under which these duties fall, but it is not necessary to quote the law word for word.) *F.—Ind.*

ANS.—To see that escapeways are constructed and maintained as required by law; that safety appliances are provided; that the proper hoisting signals are used; to split the ventilating current so that not more than fifty men work on any one current; to have break-throughs made every 45 ft. and all except that nearest the face closed and made air-tight; to see that a sufficient supply of timber is kept at the mine; to see that proper precautions are taken when approaching old works; to see that no female or boy under 14 years of age is employed in the mine.

DUTIES OF FIRE-BOSS

QUES. 2519.—What are the lawful duties of a fire-boss?

B.—Pa. (*B*)

ANS.—The principal duties of the fire-boss are defined in Article XX, Rules 9, 10, and 11 of the Bituminous Mine Law of Pennsylvania, and require the fire-boss to enter the mine before the men, having previously examined the air-current to ascertain that the air is traveling properly and in sufficient quantity. It is further stated that he shall allow none except duly authorized persons to enter or remain in any part of the mine where gas is passing in dangerous quantity. He shall frequently examine the edges and accessible parts of new falls, old gobs, and air-courses, and report to the mine foreman any attempt of persons to violate the mine law, by entering dangerous places after being warned against so doing. Article 5, Section 4, requires the fire-boss to place and maintain at each entrance of the mine, proper danger signals to prevent any but authorized persons passing into the mine, and where the circulation is stopped temporarily he must fence off each entrance to the mine, placing the proper danger signal on such fence. He is further required to notify the mine inspector of any attempt of an unauthorized person to pass such danger signal. Section 7 requires that he shall have charge of all safety lamps used for examining the mine or workings therein, which shall under his direction be cleaned, filled, trimmed, examined, and delivered locked, and in a safe condition, to the men entering the mine at the beginning of each shift, and received from the men at the end of the shift by a duly authorized and competent person. Article 6, Section 8, requires the fire-boss after each examination of the mine to enter in a book kept for that purpose a record of the examination made and to date and sign the same. He must also report verbally any danger he may have found existing in the mine, to the mine foreman, whose duty it is to see that such danger is removed, or the portion of the mine where it exists carefully guarded.

NOTE.—This question is often asked in any of the following ways: "What are the duties of a mine examiner as defined by law?" "What are the duties of mine fireman as provided by the Special Rules?" "What duties devolve upon mine foremen to prevent accidents from falls of roof slate and coal?" "State what you would enter on the fire-boss' report book after an examination of the mine has been made, so as to comply fully with the requirements of the mining law."

QUES. 2520.—After making your report and returning into the mine, what would you consider the duty of a fire-boss?

B.—Pa. (*B*)

ANS.—In a gaseous mine, the duties of a fire-boss after making his daily report are to act as assistant mine foreman in superintending the fixing of doors, regulators, brattices, important timbering, etc. In a gaseous mine, to visit those places which may have been discovered to be dangerous in the first examination, and to examine the same to ascertain if there is any change in their condition. He should give his particular attention to such places from time to time during the working hours. Always upon entering

the mine, his first duty should be to assure himself that the air is moving properly on the intake airway. He should also acquaint himself with the condition of the return current to ascertain if any unusual quantity of gas is being given off in the mine. He should devote his spare time to the examination of the abandoned portions of the mine workings in order to ascertain if there is a large body of gas accumulating in such workings. He should examine carefully any new falls upon the entries or working places of the mine. While the particular attention of the fire-boss should be devoted to the examination of the places mentioned, he should, as far as possible, visit every working place in his district, and should observe carefully the condition of the workmen's lamps, the timbering of the places, and the gaseous condition of the current.

QUES. 2521.—When do the responsibilities of a fire-boss cease? Explain fully. *B.—Pa.* (*B*)

ANS.—Under the Bituminous Mine Law of Pennsylvania the responsibility of the fire-boss appears to cease when he has placed the proper danger signals at such mine entrance or working place where a dangerous condition exists. He should, however, make himself morally certain that these signals will not be disobeyed, as far as this is practicable or possible. The moral responsibilities of a fire-boss should not cease until he has done everything in his power to avert a possible accident.

QUES. 2522.—What portions of a mine would you most carefully examine in your rounds as a mine examiner? *E.—Ill.*

ANS.—The most careful attention should be given to those portions of the mine giving off gas, or where explosive conditions are liable to exist. Also, careful attention should be given to such portions as present dangerous conditions from weak or treacherous roof, or such portions as are difficult of ventilation or drainage. The ventilation, timbering, and drainage of a mine constitute the most important matters requiring the examiner's attention.

QUES. 2523.—What are the laws in reference to persons seeking certificates as mine examiners? *E.—Ill.*

ANS.—Candidates must be 21 years of age, of good repute and temperate habits; they must pass a satisfactory examination as to their experience in gaseous mines and their knowledge of the properties of mine gases and ventilation, the principle and use of the safety lamp, and the state mining laws.

CHAPTER XXVII

MISCELLANEOUS

QUES. 2550.—In what respects is mining at once a science and an art? *I.—Pa. (A)*

ANS.—The operations of mining, as conducted at the present time, require an accurate knowledge of the principles of mechanics, geology, physics, chemistry, and other sciences. The introduction of complicated machinery requires that a workman shall not alone understand more or less of the theory underlying the operation of such machinery, but shall also possess a certain amount of skill in operating it.

QUES. 2551.—State the tonnage of coal mined in the state of Alabama for the year 1900. Also the approximate tonnage for the United States. Also the rank held by Alabama among coal-producing states. *F_1.—Ala.*

ANS.—The 1900 tonnage for Alabama was about 8,248,000 T., and for the United States over 205,000,000 T. of bituminous coal and over 51,000,000 T. of anthracite. I believe Alabama has now fifth place among the coal-producing states, ranking after Pennsylvania, Illinois, West Virginia, and Ohio, in the order named.

QUES. 2552.—What is the best proportion for a speaking tube for any given length? What is the most suitable? *F.—Pa. (A)*

ANS.—The best proportion for the diameter of a speaking tube, in reference to its length, is ½ in. in diameter to 100 ft. in length; thus, a speaking tube 300 ft. long should be 1½ in. in diameter. There is, however, a practical limit to the size and length of a speaking tube; experiment has shown that the diameter of the tube should not exceed 2 in., and the length of the tube, even in extreme cases, should not exceed 800 ft. A tube 13 in. in diameter is required to make the speech barely audible at a distance of 1 mile; this distance, therefore, is too long a range for a speaking tube. Metal tubes with smooth inside surfaces and having rounded bends are the best for speaking.

QUES. 2553.—Explain five important features of the Mine Law of Alabama. *F_1.—Ala.*

ANS.—Five important features of the Alabama Mine Law are as follows:

Sec. 8.—The superintendent of every coal mine shall provide and maintain ample means of ventilation to an extent that will dilute, carry off, and render harmless, the noxious gases generated in the mine.

Sec. 17.—No person shall act as foreman in any coal mine generating explosive gases unless he is in possession of a first-class certificate of competency.

Sec. 19.—The owner, agent, or operator of any mine shall make an accurate map of said mine, showing connection with land lines, position of creeks, rivers, etc., and adjacent workings, and file the said map in the office of the chief inspector of mines.

Sec. 26.—The owner, agent, or operator of any mine where gas is known to exist, shall employ a competent fire-boss, whose duty shall be to examine every place in the mine before the men are permitted to enter for work.

Sec. 14.—When required by the chief mine inspector, two available openings from each seam to the surface shall be maintained in good, safe condition, by the owner, operator, or manager of the mine.

PRELIMINARY QUESTIONS

QUES. 2554.—What is your name, age, place of birth, and post-office address?

QUES. 2555.—Are you a citizen of the United States and a resident in this state?

QUES. 2556.—If a naturalized citizen, produce proof of your citizenship.

QUES. 2557.—What is your present occupation?

QUES. 2558.—How many years' practical experience have you had in the mines of this state?

QUES. 2559.—Have you had — —— years' practical experience in the mines of this state immediately preceding the examination, as required by law, and where?

QUES. 2560.—In what other states or countries have you had experience in mining or in managing mines?

QUES. 2561.—State when, at what mines, by whom employed, and in what capacity you have had practical experience in mining in the mines of this state.

QUES. 2562.—Have you had any experience in mines in this country generating explosive gases? If so, state in detail the character of such experience, the length of time employed, the nature of the employment at each mine so employed, giving names of mines and of employers.

QUES. 2563.—Have you any testimonials of character?

QUES. 2564.—Are you pecuniarily interested in any coal mine or colliery in the state?

QUES. 2565.—Are you willing to accept any district assigned to you, and reside therein during the term for which you may be appointed mine inspector?

QUES. 2566.—State fully your experience in mining in this and other countries, and particularly as to whether you have had experience in gaseous mines. *F_1.—Ala.*

ANS.—My first work about coal mines was as weighman for about one year, when I was 13 years of age; I afterwards worked in blacksmith, carpenter, and machine shops, fired boilers, and ran shaft hoisting engine for short time, ran mine pump, was master mechanic at mine, worked on engineer corps, was clerk, surveyor and engineer; superintendent and engineer for ————; also general superintendent of all the Pennsylvania mines and ovens of————Co. Came to————in 1887 as mechanical engineer at ————, afterwards was superintendent. Chief engineer and assistant general manager of————Co., from————to————. Graduated from————College, a commercial and technical school, with first honors when I was between 18 and 19. Was superintendent of the————Mines of the————Co. at 19, superintendent of the————Co. at 20, general superintendent and engineer of all the mines and coke works of the———— Co. before I was 21.

ACCIDENTS

QUES. 2567.—Make a classification of the accidents occurring in anthracite mines, and state how, in your judgment, they may be diminished. *I.—Pa. (A)*

ANS.—The accidents occurring in anthracite mines may be classed under the following general heads, given in the order of their relative importance: accidents from falls of roof or coal; accidents in connection with the movement of mine cars, machinery, etc.; accidents in connection with blasting, handling of powder, etc.; accidents in connection with mine gases; accidents in connection with shafts or steep inclines; miscellaneous. Accidents in mines are largely due to ignorance or carelessness either on the part of

the management or of the miner, and the number may be greatly diminished by a strict enforcement of the mining laws. The management and the mine foreman should not only give orders in accordance with the several requirements of the mining laws, but should see that their orders in this respect are carried out. From 40 to 50 per cent. of all accidents in mines are due to falls of roof and these are very largely the result of negligence or carelessness on the part of miners themselves and lack of proper oversight by the management. Accidents due to the explosion of gas or powder, or to being overcome by gas may be largely avoided by maintaining an ample and efficient ventilation, by greater care in the daily inspection of the workings, the handling of explosives, and the use of safety lamps where these are required. The accidents due to the movement of cars in the chamber or on the haulage roads, or to any kind of mine machinery, or to falling down shafts or slopes, may be greatly lessened by proper care and diligence on the part of those employed in or about the mine or in charge of the machinery.

Ques. 2568.—Explain, as far as possible, the causes of personal accidents in mines. *F.—Ia.*

Ans.—The chief source of personal accidents in mines, is falls of roof or coal. This is largely the result of ignorance or carelessness on the part of the miner himself. There is a natural tendency on the part of the miner to postpone the setting of necessary timber until he has finished loading out his coal, and he is thus exposed to the danger of falls while cleaning up his place. Roof slips dipping forwards over the breast coal, often result in serious accidents, since their presence is unknown to the miner and a fall of roof occurs without warning. Neglect to properly sprag the coal while mining the same causes many accidents. Again, many accidents occur in blasting coal, from going back too soon to ascertain the cause of a misshot; from the careless use of iron bars in tamping or stemming a shot; and from the neglect to warn men in adjacent working places when firing a blast. Accidents due to the explosion of a body of gas are too often due to carelessness arising from the use of naked lamps or tampering with a safety lamp or exposing a safety lamp to a strong current of air and gas, or from any improper use of a safety lamp. Accidents due to the movement of loaded cars often occur from neglect to properly sprag the car on a steep grade, or from the derailment of cars in transit. Accidents from falling down shafts or steep inclines may result either from carelessness or from the breaking of ropes, etc.

Ques. 2569.—State the chief causes of accidents in bituminous mines, and the methods you would adopt to prevent the same. *F.—Pa. (B)*

Ans.—The largest number of mine accidents arise from falls of roof or coal, owing to insufficient or poor timbering, or failure to properly sprag the coal while undercutting. The Reports of the Pennsylvania Department of Mines, 1893 to 1904 inclusive, show 61 per cent. of all the fatal accidents as

due to this cause, 15 per cent. to mine cars and machinery, 14 per cent. to explosions of gas and dust, 3 per cent. to explosions of powder, and 1 per cent. to electric shocks, the remaining 7 per cent. of accidents being due to falling down shafts, killed by mules, and other causes. A strict compliance with the state mine law, and the regulations in force at each mine, will greatly assist in reducing the number of accidents.

There should be a prompt and abundant supply of mine timber of the kind and size required; and due attention given to the prompt setting of such timber in the airways and at the working face where and when needed; a sufficient quantity of air properly conducted to the working face; a careful and thorough examination of the entire mine, both with respect to gas and the condition of the roof and coal; together with proper care in the handling of explosives, the charging and firing of holes, the careful use of locked safety lamps where required. The mine foreman should give his prompt attention to all dangerous places in and about the mine as soon as his attention is called to the same. He should not only instruct the miners in reference to the proper timbering of their places, but should see that this work is done at once and the place made secure, or else should compel the miner to leave his place until such work can be performed as is necessary to make his working place safe.

QUES. 2570.—What are the necessary supplies that should always be on hand at the mine for the safe working of the same, and what is your duty in the case when your supplies are not on hand when needed? *F.—Pa.* (*B*)

ANS.—There should always be on hand an abundant supply of timber of the size and kind required in the mine; also, all other needed supplies such as boards, brattice cloth, spikes, ties, tracking, rails, nails, tools, iron, and other material necessary for making repairs. There should be also maintained at the mouth of every pit such material as would be of use, in case of accident, for the treatment of burns, bruises, broken limbs, etc., as, for example, bandages, splints, linen, boiled oil, or olive oil, as well as stretchers, woolen and waterproof blankets, and ambulance. When such supplies are not kept at the mouth of the mine in sufficient quantity, it is the duty of the mine foreman to withdraw the men until they are obtained.

QUES. 2571.—Name the supplies required by law to be kept at all mines for the care of injured persons, and in case a person is injured, state fully what steps you would take to care for him. *F.—Pa.* (*B*)

ANS.—The Bituminous Mine Law of Pennsylvania requires the operator or superintendent to keep at the mouth of the mine, or at such other place about the mine as shall be designated by the mine inspector, a stretcher, and a woolen and a waterproof blanket in good condition for use, besides bandages and linen. Where more than 200 persons are employed, two stretchers, two woolen blankets, and two waterproof blankets must be kept.

In mines generating firedamp, it is required besides, that a sufficient quantity of linseed or olive oil must be kept always on hand ready for use. In case of serious injury, word should be promptly sent to the surface summoning a doctor, and the person injured should be carefully and promptly removed to a place where he will have good air. Where a hospital room is provided in the mine, the person is carried there as soon as possible, to await the arrival of medical or surgical aid. The treatment of the patient will depend on the character of the injury; when possible, he should lie on his back with the head slightly raised if that is injured; otherwise, the head should be laid on a level with the body. If the patient is unconscious, loosen all collars, waist bands, and belts. Cold water dashed in the face, and the continued rubbing of the limbs and body will assist to revive consciousness. If this fail, artificial breathing must be resorted to; this action will imitate that of breathing, and assist to force air into the lungs and revive the patient; the fumes of ammonia or smelling salts will also be beneficial. Where bleeding results from the injury, means should be taken to stop the flow of blood, especially if from the arteries, which will be indicated by its bright red color, the venous blood being dark. This is accomplished by binding a cord or rope tightly around the bleeding member above the wound, or between the wound and the heart; a knot previously tied in the bandage or rope causes it to press more tightly against the artery and to stop the flow of blood; a short stick is often inserted, and the bandage tightened by twisting the stick. Where bones are broken, care should be taken to avoid further jar than necessary to the shattered parts. The use of stimulants should be avoided as far as possible, except as given by medical advice.

QUES. 2572.—What supplies and appliances should be on hand at all bituminous mines, for the safe working of the mine and for use in case of accidents? *I.—Pa. (B)*

ANS.—Besides the usual supplies of props, caps, and timbers of the sizes used in the mine, there should be always on hand a sufficient quantity of oak tracking, iron rails, iron pipes, ties, spikes, brattice cloth, boards, nails, etc., together with a sufficient number of extra lamps and tools to be used in case of emergency. The mine law also requires that there be kept on hand at the mines a full supply of all materials required to preserve the health and safety of the employes; also, a stretcher properly constructed, and a woolen and waterproof blanket in good condition for use; or, where more than 200 persons are employed, two stretchers, two woolen and two waterproof blankets shall be provided; and in mines generating firedamp a sufficient quantity of linseed or olive oil, splints, bandages, and linen shall also be kept on hand for use in case of accident.

QUES. 2573.—Give a concise but comprehensive explanation of the term aerophore.

ANS.—An *aerophore* is a respirator of the Fleuss type to be worn by a person traveling in irrespirable air. It consists of a case or tank that is charged with pure air at high pressure, and provided with a reducing valve

and tube having a mouthpiece at one end, by which the pure air is drawn out of the tank into the mouth and lungs as needed. This tank, which is worn or carried on the back, contains, in a separate chamber, caustic soda to absorb the carbonic-acid gas respired from the lungs, and thereby purify the air for use again.

QUES. 2574.—How would you proceed, legally, to guard the health and safety of the workmen and the security of a mine placed under your charge? *F.—Pa.* (*A*)

ANS.—A strict compliance with all the requirements of the mine law relating to the health and safety of the workmen should be enforced.

QUES. 2575.—What regulations should a mine foreman enforce to prevent accidents to drivers and all other employes on haulage roads? *F.—Pa.* (*B*)

ANS.—No one should be permitted to travel upon a haulage road where rope or motor haulage is employed except it may be a track walker whose duty it is to patrol the haulage road; and no person other than the driver or trip runner may ride on a loaded car. In mule haulage, strict regulations should be enforced relative to the movement of cars upon descending grades. Where sprags are used, there should be plenty of them at the point where they are required to be used, and no car should be permitted to descend the grade without being properly spragged. Strict regulations should also be enforced in regard to the passing of loaded and empty trips on single-track roads. It is generally customary for two or more drivers to be employed moving the cars from one parting to another, and these drivers should work together taking the loads out and the empties in to avoid danger of collision. Cars left on sidings or elsewhere must be secured against running away, and cars must not be left on the main track where they will endanger another driver.

QUES. 2576.—Describe your course of action as mine foreman in case of a fatal accident taking place at a mine under your charge. *F.—Pa.* (*A*)

ANS.—The serious nature of the accident will determine largely the action of the mine foreman or person in charge at the time. Every effort should be made to rescue the victims of the accident, and to give the best possible aid to the injured. Medical help should be summoned at once if needed. It may be necessary to organize a rescuing party to enter the mine and conduct the work of rescue. In such case, prompt action and good judgment are required on the part of the mine foreman. Notice should be sent promptly by the mine foreman to the inspector of mines for the district in which the accident occurred, informing him of the nature and time of the accident and of its results. This notice should be made in writing, and should specify the name, age, and occupation of the person killed or injured, as also the nature and character of the accident, and of the injury caused thereby.

QUES. 2577.—In case of an accident in which a miner has received a wound severing an artery, what would you do to prevent hemorrhage before a physician arrives? *F—Ia.*

ANS.—In case the wound is in the arm or leg, a rope or strong bandage is tied tightly around the wounded member between the wound and the heart. A short stick is inserted under the bandage, and the latter tightened by twisting the stick. A small pad, block, or stone, is also inserted under the bandage, in such a manner as to press against the severed artery to stop the flow of blood from the heart to the wound. In case several small arteries are severed and the wound is in such a part of the body where the flow cannot be readily stopped in this manner, it is usual to apply sulphate of iron to the wound either in powdered form or in a strong solution by means of a sponge. The sulphate of iron coagulates the blood and stops the flow. In case of bleeding from the lungs, when the blood is coughed up, the only recourse is to insist on perfect rest in a cool bed with head and shoulders slightly raised. Let the patient swallow small pieces of ice and restore his confidence, as far as possible, by assuring him there is no danger. Bleeding sometimes occurs from the stomach, when the blood looks dark and clotted. Give small pieces of ice to swallow and ice water to drink, and several doses of a teaspoonful of vinegar at short intervals, also place cracked ice wrapped in a towel over the stomach. In all cases send for a physician at once.

MECHANICS

QUES. 2578.—What load will a round iron bar of 1 inch in diameter carry, the tensile strength of the iron of which it is composed being 56,000 pounds? *M.—Ill.*

ANS.—The sectional area of the bar is $.7854 \times 1^2 = .7854$ sq. in.; then,

$$\frac{.7854 \times 56{,}000}{2{,}000} = 22 \text{ T.}$$

QUES. 2579.—What weight can be lifted with a screw jack that requires two revolutions to raise 1 inch, the length of lever being 20 inches and friction to be omitted? *M.—B. C., Canada*

ANS.—Disregarding friction and assuming that a force of 100 lb. is applied at the end of a lever 20 in. in length, the weight lifted is

$$W = 2(2 \times 3.1416 \times 20 \times 100) = 25{,}132.8 \text{ lb.}$$

CHAPTER XXVIII

STATE REGULATIONS GOVERNING CERTIFICATED POSITIONS

INTRODUCTION

The states and provinces in North America requiring certificates based upon examinations in connection with positions about the mines are shown in the following table; the detailed regulations in regard to certificated positions, whether based upon an examination or upon a service requirement without examination, are given in the following pages for each state in the United States and for Nova Scotia and British Columbia.

Unless otherwise stated, certificates are granted as the result of an examination held by an examining board.

The regulations governing the granting of certificates and the salaries of different positions, etc. are subject to change at any time, although in the older mining states the changes are minor and the present regulations will probably hold substantially as they are for some time to come. This chapter can therefore serve merely as a guide, and while it will be revised from time to time in order give the latest possible regulations, the mine law in each state should be consulted when seeking exact information along the lines of certificated positions.

The department in each state to which application should be made for information regarding the certificated positions is as follows:

Alabama: Mine Inspector, Birmingham, Ala.

British Columbia: Department of Mines, Victoria, B. C.

California: State Mining Bureau, San Francisco, Cal.

Colorado: Inspector of Coal Mines, Denver, Colo., for coal mining information, and Bureau of Mines of Colorado, Denver, Colo., for metalliferous mining.

TABLE I

CERTIFICATION REQUIRED BY LAW IN DIFFERENT STATES

Mine Inspector	Mine Manager	Mine Foreman	Assistant Mine Foreman	Fire-Boss	Miner	Shot Lighter	Hoisting Engineer
Ala.		Ala.**					
B. C.	B. C.†	B. C.		B. C.	B. C.	B. C.	
Colo.*							
Ill.		Ill.§		Ill.§			Ill.
Ind.		Ind.†		Ind.†			Ind.†
Iowa		Iowa†		Iowa			Iowa†
		Mont.					
	Nova Scotia	Nova Scotia	Nova Scotia	Nova Scotia	Nova Scotia	NovaScotia	Nova Scotia
Penna. (Anth.)		Penna. (Anth.)	Penna. (Anth.)		Penna. (Anth.)		
Penna. (Bit.)		Penna. (Bit.)		Penna. (Bit.)			
Tenn.‡		Tenn.	Tenn.	Tenn.			
Utah		Utah		Utah			
Wash.							

*The coal-mine inspector only is required to pass an examination.
†Service certificate also provided for by law.
**Must also be endorsed by two competent mining men.
‡Must hold foreman's certificate, class A.
§In Illinois the mine foreman is known as mine manager and the fire-boss as mine examiner.

Idaho: State Mine Inspector, Boise, Idaho.

Illinois: Secretary, Bureau of Statistics, Springfield, Ill.

Indiana: Inspector of Mines, Capitol Building, Indianapolis, Ind.

Indian Territory: United States Land Office, Department of the Interior, Washington, D. C.

Iowa: Secretary of Mining Department, Capitol Building, Des Moines, Iowa.

Kentucky: Chief Mine Inspector, care The State Agricultural and Mechanical College, Lexington, Ky.

Maryland: State Department, Capitol Building, Annapolis, Md.

Michigan: Commissioner of Labor, Lansing, Mich.

Missouri: Inspector of Coal Mines, or Inspector of Lead and Zinc Mines, Jefferson City, Mo.

Montana: Inspector of Mines, Capitol Building, Helena, Mont.

New Mexico: United States Land Office, Department of the Interior, Washington, D. C.

New York: Department of Labor, Albany, N. Y.

Nova Scotia: Commissioner of Public Works and Mines, Halifax, Nova Scotia.

Ohio: Chief Inspector of Mines, Columbus, Ohio.

Pennsylvania: Chief of the Department of Mines, Harrisburg, Pa.

Tennessee: Chief Mine Inspector, Nashville, Tenn.

Utah: State Coal Mine Inspector, Salt Lake City, Utah.

Washington: State Inspector of Coal Mines, Capitol Building, Olympia, Wash.

West Virginia: Department of Mines, Charleston, W. Va.

ALABAMA

INSPECTOR.—One chief mine inspector appointed by the Governor, without previously passing an examination, within 10 days from May 1, every third year, beginning 1897; term, 3 years; salary, $1,500 per annum; $1,500 per annum allowed for expenses of chief and associate inspectors. No bond required.

ASSOCIATE MINE INSPECTORS.—Two associate mine inspectors appointed by the Governor, without previously passing an exami-

nation, within 10 days from May 1; terms, 3 years each, alternating, beginning 1898 and 1899, respectively; salary, $1,200 per annum each. No bond required.

Qualifications.—The chief mine inspector and the two associate inspectors must be practical miners with at least 5 years of experience; neither they nor their wives may own or operate wholly or in part, any mining property.

Mine Foreman.—A mine foreman requires certificate of competency granted by the board of examiners to all applicants passing a satisfactory examination, and who are citizens of Alabama, and men of good moral character and known temperate habits, being at least 23 years of age and having had at least 5 years of practical experience, after 15 years of age, as miners or superintendents at or inside of any coal mine. Each applicant must be indorsed by two competent mining men. Certificates of the first class will be granted to persons having had experience in gaseous mines; certificates of the second class will be granted to persons having had experience in non-gaseous mines. A fee of $5 for first-class certificates and $3 for second-class must be paid by each applicant, to the chief mine inspector, before the examination is begun, to be used as an examiners' fund. No credit is given for certificates granted by other states.

Board of Examiners.—The board of examiners consists of the chief mine inspector, who acts as chairman without extra pay, together with two practical miners and two operators of mines appointed by the Governor and holding office for 2 years, beginning May 1, 1897. This board meets every 6 months, usually about the middle of January and the middle of July, though the time is not fixed until a few weeks before the examination, which is held in the office of the chief inspector and remains in session not longer than 3 days. Each member of the board, except the chairman, receives $4 a day from the examiners' fund.

BRITISH COLUMBIA

Inspectors of Mines.—Inspectors of mines are appointed by the Lieutenant-Governor, who also fixes the salary of the inspector. Salary, $1,800 per annum and traveling expenses.

Qualifications.—Inspectors must hold a mine-manager's certificate and cannot act as the land agent, mining engineer, manager,

viewer, agent, or mine valuer, or as arbitrator in a mining dispute, or be the partner of any person acting in such capacity.

Mine Manager.—A mine manager must have a certificate of competency issued by the Minister of Mines after passing the prescribed examination; must produce a certificate from a duly qualified medical practitioner that he has taken a course in ambulance work, fitting him to give first aid to men injured in coal-mining operations; must satisfy the Minister of Mines as to his sobriety, experience, and general good conduct; must be a British subject, and have had at least 5 years of experience in or about the practical working of a coal mine and be at least 25 years of age. A certificate of competency or of service may be revoked as a result of an inquiry carried on by the proper court or official designated by the Minister of Mines. The maximum fee to be paid by an applicant for examination as mine manager is $10, for an applicant for certificate of service, $10; for a copy of the certificate, $5.

Board of Appointment.—A board of appointment is appointed by the Minister of Mines and is composed of two owners, agents, or managers of mines, two practical coal miners, and one inspector of coal mines, but may be increased by the addition of an equal number of managers and practical miners. This board has charge of the scope of the examinations and time at which held, and appoints examiners to carry out the examinations on such lines as are designated. Members of the Board of Appointment get no remuneration, but are allowed expenses.

Examiners.—Two or more persons, being holders of certificates of competency as coal-mine managers, and who are especially "well up" technically, are chosen as examiners to prepare papers, examine and mark answers, and to conduct the examinations under the supervision of the board, after which they report the results to the board and the board recommends to the Minister of Mines in accordance with such report. Examiners are allowed $10 a day and expenses.

Overman, Fire-Boss, and Shot Lighter.—Certificates of competency for these positions are issued by the same board that holds the examinations for mine manager, the certificates being graded as first-class for manager; second-class for overman; third-class for shift boss, fire-boss, or shot lighter. A certificate of any class includes that of any other of the same class, or of

any other lower class. The examination for certificates of competency as overman may be oral or written, or partly written and partly oral, at the discretion of the board of examiners. Examination for certificates of competency as fire-bosses, shot lighters, and coal miners shall be oral. An overman must have had at least 5 years of experience in or about the practical working of a coal mine; and shift boss, fire-boss, or shot lighter, 3 years experience. The overman, shift boss, fire-boss, and shot lighter must all produce a certificate from a duly qualified medical practitioner that they have taken a course in ambulance work fitting them to give first aid to men injured in coal-mining operations.

Qualifications.—A coal miner shall be conversant with the English language; with the mining laws; must have been employed in a coal mine for at least 12 months previous to his application and be competent to perform the duties of a coal miner. The candidate pays $1 for examination.

The board of examiners for coal miners consists of one person appointed by the Lieutenant-Governor, one appointed by the owner or the manager of the colliery, and one coal miner actually working in the colliery who has had at least 3 years of experience as a working miner. The miner is elected by the miners working at the colliery.

CALIFORNIA

State Mineralogist.—The State mineralogist must be a citizen and resident of California, with practical and scientific knowledge of mining and mineralogy; appointed for 4 years by the Governor; salary $3,000 per annum and traveling expenses. Bond of $25,000 required. He has authority to appoint assistants with the approval of the board of trustees to carry on special investigations along technical and statistical lines, but has no supervision over the mines of the State.

Field Assistants.—Field assistants are appointed by the state mineralogist, with the approval of the board of trustees of the State Mining Bureau, whose duty it is to gather data concerning the different branches of the mining industry, which data are incorporated in special bulletins issued by the State Mining Bureau. The information collected by the field assistants is only

by courtesy of mine owners, as there is no law making it compulsory upon mine owners to furnish such information.

There are no mine inspectors in the State and no certificates of competency are required for any mining positions in the State.

COLORADO

Coal Mines

Inspector of Coal Mines.—The inspector of coal mines is appointed by the Governor, after passing examination, for 4 years; salary, $2,000 per annum and traveling expenses not exceeding $2,500 per annum for inspector and deputy; instruments, papers, books, etc. provided by the State. Bond of $5,000 required.

Qualifications.—He must be a citizen of the United States, of temperate habits, of good repute as a man of personal integrity, 30 years of age, and with at least 1 year's experience in the coal mines of Colorado and 5 years of experience in the coal mines of the United States; must possess practical knowledge of mining engineering. He must understand the different systems of working and ventilating coal mines and have a knowledge of mine gases. He shall not act as manager or agent for any coal mine or as a mining engineer for any coal company or be interested in any coal mine.

Deputy Inspector.—The deputy inspector is appointed by the inspector, without previous examination, for 4 years at a salary of $1,500 per annum and traveling expenses. No bond required.

Qualifications.—The qualifications are the same as for inspector.

Examinations for inspector are held at such time and place within Colorado as the Governor appoints.

Clerk.—A clerk is appointed by the inspector at a salary of $1,000 per annum.

Examining Board.—The examining board is appointed for a term of 4 years and is composed of one reputable engineer appointed by the Governor and four reputable coal miners appointed by the judges of four judicial districts of the state in which coal mines are located. The examiners are each paid $6 a day and 10 cents a mile mileage.

Ore Mines

Commissioner of Mines.—The commissioner of mines is appointed by the Governor for 4 years, without previous examina-

tion; salary, $2,500 per annum and expenses, not to exceed $1,000 per annum. Bond of $20,000 required.

Qualifications.—He must be a citizen of Colorado with not less than 7 years of practical mining experience in Colorado and a practical and scientific knowledge of mining, mineralogy, geology, and metallurgy.

MINE INSPECTORS.—Three mine inspectors are appointed by the Commissioner of Mines, without examination, for a term of 2 years each; salary, $1,500 per annum, traveling expenses not to exceed $1,000 per annum each. Bond of $5,000 required.

Qualifications.—They must be citizens of the United States and voters in Colorado with not less than 7 years of practical mining experience in Colorado.

CLERK AND ASSISTANT CURATOR FOR STATE MINERAL COLLECTION.—A clerk and assistant curator for the State mineral collection is appointed by the Commissioner of Mines, without limitation as to term of service; salary, $1,500 per annum. Bond of $5,000 required.

IDAHO

INSPECTOR.—The inspector is elected, without first passing an examination, at a general State election for a term of 2 years; salary, $1,800 per annum and 10 cents a mile allowed for all distances actually traveled; also, necessary expenses for clerk, postage, printing, etc., provided that the amount of such mileage and expenses does not exceed $2,000 a year. Bond of $5,000 required.

Qualificaticns.—The inspector shall not be an officer, director, or employe in any Idaho mining, milling, or smelting corporation.

DEPUTY INSPECTORS.—Deputy inspectors may be appointed by the chief inspector with consent of the Governor to investigate accidents and attend inquests when the chief inspector cannot be present. For this they receive $5 a day while actually employed, all of which must come from fund for expenses, as must also the cost of publishing an annual report. There are no producing coal mines. No examinations of any kind are required.

ILLINOIS

Inspector.—Seven State inspectors of mines are appointed by the Governor, after passing examination; term, 2 years dating from October 1, following appointment; salary, $1,800 per annum and actual traveling expenses, payable quarterly. Bond of $5,000, approved by the Governor, required.

Qualifications.—An inspector must be a citizen of Illinois; at least 30 years of age; have at least 10 years of practical mining experience; temperate habits; good reputation; a practical knowledge of mining engineering, mining machinery, and appliances, and the proper development, operation, and ventilation of coal mines, together with a knowledge of the nature and properties of mine gases, the geology of the coal measures of Illinois, and a knowledge of the State mining laws; he must not have any pecuniary interest in any coal mine, either as owner or employe. An inspector who has satisfactorily passed two of the State examinations for inspectors, and who has served acceptably as inspector two full terms, may be exempted from examination thereafter, upon making application to the examining board, and be certified to the Governor as a candidate for reappointment.

Assistant Inspector.—An assistant to the mine inspector may be appointed by the county board in mining counties, without examination, but the person appointed must hold a mine manager's certificate. The compensation depends on the number of mines to be examined, and is at the rate of $3 per day. The appointment is for 1 year.

Mine Manager.—A mine manager requires a certificate of competency, granted by the State mining board to all applicants passing a satisfactory examination, and who are citizens of Illinois and men of good repute and temperate habits, being at least 24 years of age, and having had at least 4 years of practical mining experience.

Mine Examiner.—A mine examiner requires a certificate of competency, granted by the State mining board to all applicants passing a satisfactory examination. He must be a citizen of Illinois, of good repute and temperate habits, and at least 21 years of age.

Hoisting Engineer.—A hoisting engineer must have a certificate of competency, granted by the State mining board to all

applicants passing a satisfactory examination, and who are citizens of the United States, of good repute and temperate habits, and who are at least 21 years of age, and have had at least 2 years of experience as a fireman or engineer of a hoisting plant.

STATE MINING BOARD.—The State mining board is composed of five members, two of whom are practical coal miners; one a practicing hoisting engineer; and two coal operators, one of whom must be a mining engineer. They are appointed by the State Commissioner of Labor for a term of 2 years (beginning July 1, 1899); $5 per day and traveling expenses are paid each member of the Board for not more than 100 days in a year. Examination for inspector is held biennially, beginning with 1899, on the second Tuesday in September. Each candidate, before taking the examination, must pay $1 as an examination fee; and before receiving a certificate, the further sum of $2. The Board can, at its discretion, issue certificates without examination to parties with proper credentials presenting certificates from other states. Examinations for mine manager, mine examiners, and hoisting engineers are held at such times and places as shall afford the best facilities to the greatest number of candidates.

INDIANA

INSPECTOR.—One inspector of mines is appointed, after examination, by the State Geologist every 2 years, beginning 1891; term, 2 years; salary, $1,800 per annum and expenses. Two assistants are appointed by the mine inspector, after examination; salary, $1,200 per annum and expenses. A bond of $1,000 each, approved by the Secretary of State, is required of inspector and assistants.

Qualifications.—The mine inspector and assistant mine inspector must each have been a resident of Indiana for at least 5 years preceding his appointment, and must have had at least 10 years of experience in actual mining as a practical miner; must not be interested pecuniarily in any coal mine in the State, directly or indirectly. Candidates for the office of mine inspector must pass a satisfactory examination before the State Geologist, with respect to their fitness to discharge the duties belonging to the office. Candidates for assistant inspector must pass an examination before the inspector.

CLERK.—A clerk at a salary of $600 per annum is also allowed.

MINE BOSS.—A mine boss requires a certificate of competency, granted by the inspector of mines to all applicants, citizens of the United States, passing a satisfactory examination.

FIRE-BOSS.—A fire-boss requires a certificate of competency, issued by the inspector of mines to any person passing a satisfactory examination, and having the same qualifications as required for mine foreman.

A certificate of service may be granted by the inspector of mines to any person engaged as, and successfully discharging the duties of, fire-boss for at least 3 years preceding the passage of the present mine law in July, 1897.

HOISTING ENGINEER.—A hoisting engineer requires a certificate of competency, or a service certificate, granted by the inspector of mines on the same conditions as specified in regard to mine foremen and fire-bosses.

EXAMINING BOARD.—The examining board is composed legally only of the inspector of mines, though he may, and usually does, call to his assistance a hoisting engineer, one or more of the assistant inspectors, and one or more mine bosses.

INDIAN TERRITORY

INSPECTOR.—An inspector is appointed by the President of the United States, without passing examination, to serve until his successor is appointed; salary, $2,000 per annum and traveling expenses. A bond of $2,000 is required.

Qualifications.—He must be a practical miner or mining engineer; resident of the Territory for at least 6 months; shall not act as land agent, manager, or agent of any mine, or as mining engineer, or be interested in any mine in the territory.

No examinations are held for foreman, fire-boss, or hoisting engineer.

IOWA

INSPECTOR.—Three State mine inspectors are appointed by the Governor, after passing an examination; term, 2 years dating from first Monday of April following appointment; salary, $1,500 per annum and actual traveling expenses, not exceeding $750

each year. A bond of $2,000, approved by the Secretary of State, is required.

Qualifications.—Inspectors must be citizens of Iowa; at least 25 years of age; have at least 5 years of experience in the practical working of mines; good moral character; must not have acted as agent or superintendent of any mine for at least 6 months preceding examination; and must not be connected with or interested in any mine in the State. A certificate of any previous examining board in Iowa entitles its holder to stand as a candidate for appointment without submitting himself to another examination.

Mine Foreman.—A mine foreman requires a certificate of competency, granted by the examining board to any person passing a satisfactory examination. A certificate of service was formerly granted by the examining board to any person employed as, and continuously performing the duties of, mine foreman or pit boss for 4 years immediately preceding the examination, but such certificates are not now issued for service in Iowa, though they may be granted to applicants from other States.

Hoisting Engineer.—A hoisting engineer requires a certificate of competency, or a service certificate, as the case may be, granted by the examining board on the same conditions as specified in regard to mine foremen.

Board of Examiners.—A board of examiners is appointed by the Executive Council for a term of 2 years; it consists of five members, including two practical miners and two mine operators, all of whom must hold certificates of competency as mine foremen; and one at least must hold a certificate as hoisting engineer; also one mining engineer. Each member of the board must have at least 5 years of experience in his particular profession and must not be interested in any school, scheme, plan, or device having for its object the preparation, education, or instruction of persons in the knowledge required for certificate of competency. The board holds an examination for inspector on the first Monday in March of each odd-numbered year, and notice of the examination must be given in one newspaper in each mining district not less than 15 days before the examination. Examinations for mine foreman and hoisting engineer are held at such times and places as the board may select, and in their selection consideration is given to the convenience of the applicants for certificates. Each member of the board receives traveling expenses and $5 a day,

but shall not receive compensation for more than 10 days ($50) for holding the examination for mine inspector, or for more than 70 days in any one year for holding examinations for mine foreman and hoisting engineer. Each applicant for a certificate as mine foreman, pit boss, or hoisting engineer pays a fee of $2 to the examining board, before examination; and each successful applicant, $2 before the certificate is granted, which money is paid into the State treasury by the examining board.

Certificates from other states are not accepted in lieu of examination.

KANSAS

INSPECTOR OF MINES.—Delegates elected annually by the miners' unions meet at the State capitol on the first Monday in February every year, where they elect a president, vice-president, and secretary of the State Association of Miners, the secretary to serve ex officio as State mine inspector; salary $1,500, with allowed expenses not exceeding $1,000.

Qualifications.—He must be a citizen of the United States and have been a resident of Kansas for 2 years prior to appointment; must be of temperate habits, of good repute and personal integrity, and at least 30 years of age. He must have had 5 years of practical experience working in and around coal mines and must satisfy the Governor and Executive Council that he has a sufficient knowledge of coal mines and of noxious gases. He must reside in the State, and shall not act as manager, agent, or mining engineer for any coal mine, or be interested in the operation of any coal mine in the State.

DEPUTY MINE INSPECTORS.—Deputy mine inspectors are appointed by the inspector of mines, with the permission of the Executive Council—one for each of the counties of Crawford, Cherokee, Osage, and Leavenworth, provided that no one is appointed in the county in which the State mine inspector resides; they are under the supervision and control of the State mine inspector and hold the positions at his pleasure; compensation $3 per day actually employed and actual traveling expenses.

KENTUCKY

INSPECTOR OF MINES.—The Dean of the Department of Mining Engineering in the State Agricultural and Mechanical College, at Lexington, is, by law, chief inspector of mines. He is appointed by the board of trustees of said college, as other professors are selected, and holds his position on the same conditions as other professors of the college, being subject to removal as they are. Salary, $1,800 per annum and traveling expenses. A bond of $5,000 is required. The chief inspector is also curator of the State Geological Department, and by virtue thereof (Act of 1904) is director of the State Geological Survey, which was reestablished in 1904. As curator, he receives $600 per annum. Bond required.

Qualifications.—He must have a practical knowledge of chemistry, geology, mineralogy, and of mine gases; of systems of working and ventilating mines, and of mining engineering. He shall not act as agent, manager, or mining engineer, or be interested in operating any mine in Kentucky.

ASSISTANT INSPECTORS.—There are three assistant inspectors of mines; salary of each, $1,200 per annum and traveling expenses. A bond of $2,000 is required of each. One of the assistants is appointed by the trustees of the State Agricultural and Mechanical College, and holds his position at the pleasure of the board of trustees. Two are appointed by the Governor (Act of 1906), and hold for a term of 4 years and until successors are appointed and qualified.

Qualifications.—The assistant inspectors must have a practical knowledge of mine gases, and of different systems of working and ventilating coal mines, and of mining.

MARYLAND

INSPECTOR.—An inspector is appointed, without previous examination, by the Governor and approved by the Senate for a term of 2 years; salary, $1,500 per annum, with no allowance for expenses of any kind. A bond of $2,000, to be approved by a judge of the circuit court, is required.

Qualifications.—The inspector must have had practical mining experience for at least 5 years previous to appointment. No certificate is required.

MICHIGAN

INSPECTOR OF COAL MINES.—The inspector is appointed by the Commissioner of Labor, without previous examination, no term of office specified; salary, \$3 a day and traveling expenses, the total for any one year not to exceed \$1,500.

INSPECTION OF ORE MINES IN THE UPPER PENINSULA.—The board of supervisors of any county where there are mines situated and working may appoint inspectors. The term of employment, compensation, removal, and filling of vacancies are all at the discretion of the Board of Supervisors. A bond of \$5,000 is required.

Qualifications.—This inspector must be some suitable person who is a practical miner. The Board of Supervisors may appoint as many deputy inspectors as may seem necessary who shall be under the supervision of the inspector of mines for that county and their duties shall be prescribed by him.

MISSOURI

COAL MINES

INSPECTOR.—An inspector and assistant are appointed by the Governor for a term of 2 years without examination; the salary of the inspector is \$1,500 per annum and traveling expenses. No bond is required. The salary of the assistant inspector is \$1,500 and \$80 per month traveling expenses. No bond is required.

Qualifications.—The inspector and assistant must have had practical experience in coal mining, and must not be interested in any mine in Missouri.

LEAD AND ZINC MINES

INSPECTORS.—Two inspectors are appointed by the Governor for a term of 2 years, without examination; salary, \$1,500 per annum and traveling expenses. No bond is required.

Qualifications.—They must have had practical experience in lead and zinc mining, and must not be interested in any mine in Missouri.

SECRETARY.—A secretary is allowed for the Bureau of Mines, who must be a draftsman; salary, \$1,500 per annum.

MONTANA

INSPECTOR OF COAL MINES.—An inspector of coal mines is appointed by the Governor, with the consent of the Senate, for a term of 4 years; salary, $2,000 per annum and traveling expenses; instruments and appliances are furnished by the State. A bond is required.

Qualifications.—He must be at least 30 years of age and have been employed at coal mines for 10 years prior to appointment; must be a graduate of some recognized school of mines or mining engineering, and must possess a knowledge of the different systems of working and ventilating coal mines and have a knowledge of mine gases; cannot act as an agent for any corporation, or as superintendent or manager of any mine, and shall not be in the employ of any mining company in any way whatever. When not employed in inspecting coal mines, he is subject to the call of the Governor to inspect quartz mines.

FOREMEN OR MINE BOSSES.—Foremen or mine bosses in coal mines in which inflammable gases are known to exist must have certificates of competency issued by the inspector, after an examination; must have had experience in inflammable gases and in the handling of explosives.

INSPECTOR OF ORE MINES.—An inspector of ore mines is appointed by the Governor, with the consent of the Senate, for a term of 4 years; salary, $2,400. A bond of $5,000 is required.

DEPUTY INSPECTOR OF ORE MINES.—One deputy inspector of ore mines is appointed; term of 4 years; salary, $1,650. A bond of $2,500 is required.

Qualifications.—The inspector and deputy inspector must be residents of Montana for at least 1 year preceding appointment; at least 30 years of age; theoretically and practically acquainted with mines and mining, and must not be employes or officers of any mining company or corporation while holding office. No examination of the candidate is required.

NEW MEXICO

INSPECTOR.—The inspector is appointed by the President of the United States, without passing examination, to serve until his successor is appointed; salary, $2,000 per annum and traveling expenses. A bond of $2,000 is required.

Qualifications.—He must be a practical miner or mining engineer; must be a resident of the Territory for at least 6 months; shall not act as land agent, manager, or agent of any mine, or as mining engineer, or be interested in any mine in the Territory.

No examinations are held for foreman, fire-boss, or hoisting engineer.

NEW YORK

DEPUTY FACTORY INSPECTOR.—The factory inspector is authorized to appoint from the State civil service eligible list one deputy who shall have a knowledge of mining, to inspect mines and quarries; the salary is $1,200 per annum and all necessary traveling expenses. No bond is required.

A special examination for mine inspector will be provided for by the State Civil Service Commission when requested by the Commissioner of Labor.

NOVA SCOTIA

INSPECTORS.—Inspectors are appointed, without examination, and are paid from $900 to $1,200 per annum with an allowance for expenses. No bond is required, and they hold office during the pleasure of the appointing power.

MINE MANAGER.—Every mine in which more than thirty persons are employed underground must be under the charge of a certificated manager whose certificate shall be granted by a board of examiners, as explained later.

UNDERGROUND MANAGERS AND OVERMEN.—The underground workings of every mine must be in charge of a certificated underground manager or overman whose certificate shall be granted by the same board of examiners as for mine manager.

Qualifications.—An underground manager or overman must be 21 years of age, of good moral character, and must have had 4 years of underground experience.

Board of Examiners.—The board of examiners shall consist of the inspector of coal mines, three mine managers, three working miners, and three persons who shall be experienced mining engineers, or deputy inspectors of mines, or other persons of experience in coal mining, and not employed in or connected with any mine in operation. This board of examiners shall draw up rules for its own guidance, and shall hold such examinations as it thinks best, reporting from time to time to the Commissioner of Mines the names of such persons as are qualified to receive certificates. Members of the board shall be appointed by the Governor in Council, who shall also determine the fees and traveling expenses to be paid the board of examiners, and the fees to be paid by applicants for certificates.

Certificated Miner.—No person can be employed as a miner to cut, mine, bore, blow, shear, loosen, or extract coal in any way, unless he has been employed in some capacity in a mine for a period of 1 year and holds a certificate to that effect from a board of examiners for workmen.

Shot Firer.—No person can be employed as a shot firer unless he holds a certificate of competency as such from the board of examiners for workmen. The board of examiners for workmen is constituted as the Governor and Council deem requisite.

Hoisting Engineers.—Hoisting engineers must have certificates granted by the board of examiners, and they must have had 3 years of experience about boilers, engines, and machine shops to qualify them for an examination for hoisting engineer.

OHIO

Chief Inspector.—The chief inspector is appointed by the Governor, with the consent of the Senate, for 4 years; salary, $2,000 a year. A bond of $5,000 is required. Jurisdiction extends over all mines and quarries within the State.

Qualifications.—He must possess a knowledge of chemistry, geology of Ohio, and mineralogy as far as these relate to mining; a practical knowledge of mine gases and the different systems of working and ventilating gaseous mines; shall not act as agent,

manager, or mining engineer for any operator or be interested in operating any mine in Ohio.

District Inspectors.—Seven district inspectors are appointed by the chief inspector, with approval of the Governor, for 3 years; salary, $1,200 and necessary instruments. A bond of $2,000 is required.

Qualifications.—Each shall have had 5 years of experience as a practical miner; 2 years' residence in district for which appointed; practical knowledge of mine gases, their detection and removal, and the working and ventilating of gaseous mines; shall not act as agent, manager, or mining engineer for any operator or be interested in operating any mines in Ohio.

PENNSYLVANIA

Chief of Department of Mines.—The Chief of the Department of Mines is appointed by the Governor, by the advice and consent of the Senate, without previous examination, every 4 years, beginning 1903; salary, $4,000 per annum and traveling expenses. A bond of $10,000 is required.

Qualifications.—He must be a competent person who has had at least 10 years of practical experience in the working and ventilation of coal mines of Pennsylvania, and with a practical and scientific knowledge of all the noxious and dangerous mine gases, and must have the qualifications of an inspector (see law); must not act as manager, viewer, or agent of any mine or colliery, nor be interested in any colliery.

Deputy Chief of Department of Mines.—The Deputy Chief of the Department of Mines is appointed by the chief of the department for a term of 4 years; salary, $2,500 per annum. No qualifications specified and no bond required.

Anthracite Region

Inspectors.*—District mine inspectors are elected at the general November election under Amendment to Article 2, Section 7, of the Anthracite Mine Law, approved June 8, 1901; term, 3 years dating from first Monday of January following the election; salary, $3,000 per year and expenses. No bond required.

Qualifications.—The inspector must be a citizen of Pennsylvania; at least 30 years of age; have at least 5 years of practical experience

*Fifteen in 1906.

in anthracite mines of Pennsylvania; experience in gaseous mines; practical knowledge of different systems of working coal; certificate of State examining board must be filed with the County Commissioners previous to the nomination for election. Inspector cannot act as agent or manager of any coal mine, or hold any pecuniary interest in same during his term of office.

BOARD OF EXAMINERS.—A board of examiners composed of three reputable coal miners in actual practice and two reputable mining engineers is appointed by the judges of the county court at the first term of court each year to hold office during the year. Compensation is $5 a day while sitting and 6 cents a mile for mileage. Notice of examination must be given in not more than five newspapers in the district at least 2 weeks before examination, and at least one examination must be held each year, at least 6 months before the general election in November. An inspector, at the end of each term of office, must pass an examination before reappointment.

Certificates from other states are not recognized in Pennsylvania, and no credit is given for a bituminous certificate in the anthracite region. Certificate must be signed by at least four of the examiners, and certificate granted only to those making 90 per cent. in examination. Names of successful applicants must be published in at least two papers.

MINE FOREMAN.—A certificate of competency to act as mine foreman or assistant mine foreman is granted by the Chief of the Department of Mines to all applicants reported by examining boards as having passed a satisfactory examination, as having had at least 5 years of practical experience as a miner, and as being of good conduct, capability, and sobriety.

BOARD OF EXAMINERS.—The board of examiners is composed in each inspection district of the district inspector of mines, ex officio, and of two practical miners and one mine owner, operator, or superintendent appointed by the judges of the county court at the first term of court each year, to hold office for 1 year. The compensation is $6 a day and 5 cents per mile for distance traveled for each member of the board excepting the inspector, and the board shall not sit more than 10 days in any year. Date and place of holding examination not specified, but usually held in the largest city in each district some time in June or July. Each applicant must pay $1 for examination, $1 for registration of

certificate, and $1 for certificate; these fees to be transmitted to the Department of Mines.

FIRE-BOSS.—Before any person can perform the duties of fire-boss, he must file with the district inspector of mines a copy of his deposition, made before an alderman or justice of the peace or other person authorized to administer oaths, stating that he has had 5 years of practical experience in mines as a miner, at least 3 of which have been in gaseous mines.

More or less confusion has existed in regard to the positions of assistant mine foreman and fire-boss. The Department of Mines has ruled that every fire-boss in the anthracite regions must be a holder of an assistant mine foreman's certificate. All fire-bosses now have such certificates. The law requires that the workings must be examined each morning before the miners enter the mine, by the foreman or his assistant, and that the fire-boss shall see that no one enters the mine until the foreman or his assistant has reported the mine to be safe.

MINERS' CERTIFICATES.—Before being employed as a miner in an anthracite mine, a person must receive a certificate from the miners' examining board certifying that the holder has served 2 years as a miner or mine laborer in an anthracite mine and has answered intelligently and correctly at least twelve questions in the English language pertaining to the requirements of a practical miner. A fee of $1 must be paid before the certificate is issued and 25 cents for registering the certificate. Such certificates are good anywhere in the anthracite region, but a miner moving to another inspection district must have his certificate registered in that district at a cost of 25 cents.

The examining boards are composed of nine miners, who have had 5 years of experience in the anthracite field, appointed by the judge of the county court; compensation is $3 a day and expenses; that is, if enough certificates are issued to make up same amount.

BITUMINOUS REGION

INSPECTORS.*—District mine inspectors are commissioned by the Governor, after passing examination; term, 4 years, dating from May 15 following appointment; salary, $3,000 per year and actual traveling expenses, payable quarterly; bond of $5,000, approved by the presiding judge of the district, is required.

*Eighteen in 1906.

Qualifications.—The inspector must be a citizen of Pennsylvania; of temperate habits; have a reputation for integrity; be at least 30 years of age; have at least 5 years of practical experience in bituminous mines of Pennsylvania, immediately preceding the examination; experience in gaseous mines; practical knowledge of the working and ventilation of mines and the properties of gases; and certificate of examining board must be filed in the office of the Department of Mines previous to appointment.

Board of Examiners.—The board of examiners is appointed by the Governor, in the month of January, for 4 years. It is composed of two mining engineers of good repute and three other persons who have passed examination for inspector, or mine foreman in mines generating firedamp, who shall be citizens of Pennsylvania, 30 years of age, and have had at least 5 years of experience in the bituminous mines of Pennsylvania, and shall not hold any official capacity at mines. An examination is held the first Tuesday in March in Pittsburg and is both oral and written. No person may receive certificate whose percentage is less than 90, and each certificate must be signed by at least four members of the board. After the examination, each person examined must be furnished by the board with a printed list of all questions, oral and written, asked in the examination and with each question marked solved right, imperfect, or wrong. This board also has authority, when called together by the Governor for an extra session, to revise the division of the bituminous coal region into inspection districts, as experience may prove to be advisable. Each member of the board receives $10 a day while actually employed, and traveling expenses. At the end of each term of office, an inspector must pass an examination before reappointment. No credit is given a certificate from another State or from the anthracite region in Pennsylvania.

Mine Foreman.—A certificate of competency to act as mine foreman is granted by the Chief of the Department of Mines to all applicants passing a satisfactory examination, and who are citizens of Pennsylvania and men of good moral character and known temperate habits; at least 23 years of age; and who have had at least 5 years of practical experience, after 15 years of age, as miners or superintendents at or inside of the bituminous mines of the State. Certificates of the first grade are granted to persons having had experience in gaseous mines; certificates

of the second grade are granted to persons having had experience in non-gaseous mines. A service certificate is granted by the examining board, to persons holding the position of mine foreman at any mine, which permits its holder to act in the same capacity at any other mine in the State having like conditions with respect to health and safety.

Board of Examiners.—The board of examiners consists of a mine inspector, one operator or superintendent, and one miner who shall have received a first-grade certificate of competency as mine foreman, appointed by court of common pleas for term of 4 years, and meetings held annually upon call of mine inspector, usually the second week in January. Compensation, $5 a day and 3 cents a mile mileage. Each applicant who passes pays $3 fee to be transmitted to the Department of Mines.

Fire-Boss.—A certificate of competency is granted, by the same examining board that holds examinations for mine foreman, to all applicants passing a satisfactory examination and having the same qualifications as those required of mine foremen.

TENNESSEE

Inspector.—A chief mine inspector is appointed by the Governor; term, 4 years; salary, $2,200 per annum, payable monthly, and actual traveling expenses not exceeding $1,000 per annum; also postage, stationery, instruments, test lamps, telegraph and telephone expense, printing, tabulating reports, etc.; a bond of $15,000, approved by the Governor, is required.

District Mine Inspectors.—Two district mine inspectors are appointed by the chief inspector, with the approval of the Governor; term, 2 years; salary, $1,320 per annum, payable monthly, and actual traveling expenses not exceeding $750 each per annum. A bond of $5,000, approved by the Governor, is required. The jurisdiction of the mine inspectors extends over both coal and ore mines.

Clerk.—One clerk is appointed by the chief mine inspector; salary, $1,200 per annum, and actual expenses when required to leave office.

Qualifications.—The chief mine inspector and the two district mine inspectors must be citizens and residents of Tennessee for at least 2 years preceding appointment; of good moral character and temperate habits; have at least 6 years of experience in mining;

a practical knowledge of mining engineering and the different systems of working and ventilating mines, and the nature and properties of noxious mine gases; together with a competent knowledge of chemistry, geology, and mineralogy, as relating to the mines of Tennessee; must not be owner, agent, operator, stockholder, superintendent, engineer, or foreman in any mine. The chief inspector and the district inspectors must have a foreman's certificate Class A (for gaseous mines), but are not required to pass another examination before reappointment. The chief inspector must also be a mining engineer.

Mine Foreman.—A certificate of competency to act as mine foreman or assistant mine foreman is granted by the Secretary of State to all applicants reported by the examining board as having passed a satisfactory examination, and having had at least 5 years of practical experience in mining, and being of good conduct, capability, and sobriety.

Board of Examiners.—The board of examiners is composed of one experienced miner, one operator or manager of mines, and one expert mining engineer; appointed by the Governor for a term of 2 years; compensation, $5 a day and traveling expenses for not more than 40 days during one term. A meeting is held upon request of the Governor or chief mine inspector at times and places convenient for board and applicants, and when the board is notified by the Governor or chief mine inspector that there is a sufficient number of applicants to warrant an examination. A fee of $3 is paid by each applicant for certificate, before the examination, $1 for the certificate, and $1 for registering the certificate. No credit is given to certificates granted by other states.

Gas Boss.—A certificate of competency as gas boss is granted by the Secretary of State to all applicants reported by the examining board as having passed a satisfactory examination before the same board and under the same conditions as mine foremen, and having the same qualifications as required for mine foremen. Must have had sufficient experience with gases; that is, he can act as helper with gas boss and get practical experience in that way, and then apply for examination as to qualification.

UTAH

COAL-MINE INSPECTOR.—There is one coal-mine inspector appointed by the Governor, with the consent of the Senate, for a term of 4 years, dating from March; the salary is $2,000 per annum, and actual necessary traveling expenses incurred in the proper discharge of his official duty. A bond of $10,000 is required, which must be approved by the Secretary of State.

Qualifications.—The person appointed must have attained the age of 30 years; must have a knowledge of the different systems of working coal mines; and must produce satisfactory evidence to the Governor of having had at least 5 years of practical experience in the coal mines of Utah. He must have had experience in coal mines where noxious and explosive gases are evolved, and must hold the certificate of examination required by law to be held by mine foreman of the State.

MINE BOSS.—A mine boss must have a certificate of competency granted by the board of examiners.

BOARD OF EXAMINERS.—In every county where coal and hydrocarbon is mined, there is a board of examiners, consisting of the State mine inspectors, one operator of coal mines, and one coal miner, all of whom shall be citizens of the United States and the latter two of whom shall have at least 5 years of experience in the mines of the State. It is the duty of the board to examine any person applying, as to his competency and qualification to discharge the duties of mine boss. The board meets at the call of the inspector.

The board of examiners is appointed by the district court in any county upon the request of the State mine inspector. The two members of the board, other than the inspector, hold office for 2 years, and receive $4 a day and traveling expenses while on duty. Each applicant for a certificate pays $1, which goes into the State treasury.

FIRE-BOSS.—No person can act as fire-boss unless granted a certificate of efficiency by the inspector.

WASHINGTON

Inspectors.—Inspectors are appointed by the Governor, after passing examination and upon the recommendation of the board of examiners, for a term of 4 years; salary, $1,500 per annum and traveling expenses. A bond of $2,000 is required.

Qualifications.—An inspector must be a citizen of Washington, and must have had at least 5 years of practical experience in coal mining.

Board of Examiners.—The board of examiners is appointed by the Governor for 4 years; it is composed of one practical coal miner, one owner or operator of a coal mine, and one mining engineer; compensation, $5 a day while employed and 5 cents a mile mileage.

WEST VIRGINIA

Chief Mine Inspector.—One chief mine inspector is appointed by the Governor; term, 4 years; appointment is made in June; salary, $1,800 per annum, and expenses not to exceed $500. A bond of $2,000, approved by the Governor, is required.

Qualifications.—He must be citizen of West Virginia; a competent person having at least 8 years of experience in the working, ventilation, and drainage of coal mines in the State; must have practical and scientific knowledge of all noxious and dangerous mine gases.

District Inspectors.—Seven district inspectors are appointed by the Governor; term, 4 years; salary, $1,200 per annum, and traveling expenses not to exceed $500 each year. A bond of $2,000, approved by the Governor, is required.

Qualifications.—Each inspector must be a citizen of West Virginia; have good moral character; temperate habits; must have at least 6 years of experience as miner or as employe in the mines of the State; must not be interested in any coal mine in the State as owner, operator, agent, stockholder, superintendent, or engineer, during his term of office. No examination of the candidate is required.

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